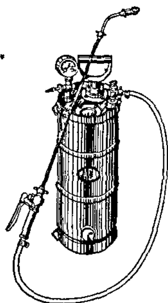
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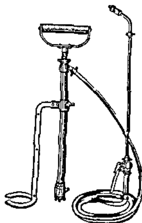


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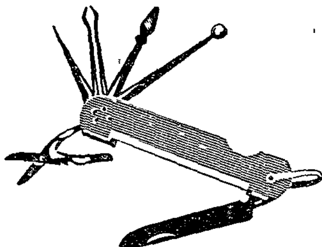
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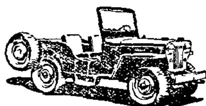
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CONTENTS

FOREWORD

No other disease has had a wider prevalence or claimed a larger toll of life than malaria Various theories about its causation were advanced from time to time, explored and exploded, till discovery by Ross in 1897, gave the world a full knowledge regarding the essential role of the female mosquito in the transmission of malaria. It is obvious that until the manner in which malarial transmission and endemicity were maintained in community was fully known, it was not possible to formulate a rational plan for preventing the spread of the disease The necessity for the presence of plasmodium in the past and vector mosquito for the maintenance of malaria transmission has been proved beyond doubt The carrier mosquito remains harmless in the absence of reservoirs of infection; nor is the infection in the past transmitted to another person in the absence of the vector mosquito If malaria has been successfully controlled during the recent years, and today we are on the threshold of eradicating the scourge from vast tracts of the tropics, it is because of our intimate knowledge of the subtle ways of vector mosquitoes and the use of powerful insecticides that intercept the transmission cycles

Ever since the importance of the mosquito as the carrier of malaria was brought to light, mosquitoes in general and the vectors of malaria in particular have been studied extensively These studies have resulted in a fund of information about the habits of insects which form an important link in the epidemiology of malaria

The difference in the behaviour of one species from that of another or the ways even of the same species in different environments are often striking *A culicifacies*, one of the most important malaria vectors in the rural parts of India is mainly associated with irrigated tracts, and breeds mainly in irrigation channels and waste irrigation water *A stephensi*, on the other hand is an urban carrier, breeding largely in wells and cisterns *A fluviatilis* and *A minimus* breed in foot-hill streams, the former is an important vector in the foothills of South India, while the latter's role as a

vector is limited to the foot hills of he eastern Himalayas The distribution of *A sandaicus* is restricted to the salt lake areas of West Bengal Orissa and Andhara States and appears to be gradually spreading southward

The transmission of the malaria parasite being a direct result of the obligatory blood feeding habit of the female mosquito, is necessarily directly proportional to the degree of man mosquito contact The increasing importance as a vector in U P Terai of *A fluviatilis* a species which had not been reported to be responsible for the transmission of malaria in this area uptill a decade back, brings out clearly now changing environments can alter the feeding habits and thereby the vectorial status of a species Another classical example is the clearing of jungles in Malaya as a measure *to reduce breeding of A maculatus which turned conditioned more* favourable for *A umbrsous*, an equally important vector in that area

In controlling malaria with the modern insecticides experience has shown that one has to be on the guard to avoid fresh hurdles that may crop up It has been correctly pointed out that the victories against malaria in different parts of the world during the last decade would not justify complacence on the part of the govern*ments of other malarious countries it should be remembered* that there can also be defeats The development of resistance by the mosquitoes to insecticide has been observed by many workers Fortunately such a phenomenon has not been encountered so far among any of the vectors of malaria in *India While planning* for an all out drive against malaria, is being evolved to eradicate the disease before the mosquito becomes resistant, the epidemiologist and the entomologist have to keep a watchful eye to detect any reduction in the susceptibility of the mosquito to the insecticide, either physiological or behaviouristic

Though about twenty species of anophelines have been found *infected in nature in India only the following species are of any* real importance as vectors,

A culicifacies	*A philippinensis*
A fluviatilis,	*A stephensi* and
A minimus	*A sundaicus*

A review of the available information regarding the vectors in general and of the principal vectors in particular has been presented

in this volume Most of the chapters have appeared as publications in the Bulletin of the National Society of India for Malaria and other Mosquito-borne Diseases It is felt that such a compilation will be of immense value to the workers engaged in different parts of the country in the National Malaria Control Programme particularly when the goal is shifted to eradication of malaria from this subcontinent Such a review of the present knowledge, apart from providing available information to the workers, serves to emphasize the lacunæ in our knowledge about the malaria vectors Cautious planning of the control measures to suit local conditions and to effectively hit the local vectors, search for new knowledge regarding the subtle ways and adaptive modifications in the carrier mosquito, are expected to be stimulated by the present review.

—*Editor*

PICTORIAL ACCOUNT OF MALARIA VECTORS IN INDIA

BY

M L. BHATIA

and

N. L. KALRA

(Malaria Institute of India, Delhi)

[June 12, 1957]

To a malariologist out in the field some aid is essential in checking up the identity of a vector anopheline An attempt has been made to do away with lengthy descriptions of morphology and present some notable morphological characters and diagramatic representation of adult females in the accompanying pages to serve as a ready reckoner

Anopheles annularis (Fig 1) —Medium sized mosquito with predominently dark general appearance, mesonotum covered with short pale scales, unspeckled legs, three hind tarsal segments completely white, V 5 extensively dark or at least dark spot at the point of bifurcation, some specimens show a dark band in the basal region of the third hind tarsal segment thus showing only two hind tarsal segments completely white

A philippinensis (Fig 2) —General appearance very similar to *annularis* but with paler wings, closely resembles *pallidus* Inner and outer prehumeral accessory dark spots on costa usually divided but in some cases basal third costa mainly dark, V 5 mainly pale as in *pallidus*, unlike *pallidus* sternopleura is usually devoid of scales, apex of hind tarsal segment 1 usually pale

A stephensi (Fig 3) —Easily distinguishable species by its speckled legs, tips of hind legs dark and speckled palpi with two distal broad and one proximal pale bands, mesonotum with obvious scales

A sundaicus (Fig 4) —Ornamentation resemble that of *subpictus* from which it is easily separable by the speckled legs, has a superficial resemblance to *stephensi* but is at once distinguishable by palpi being unspeckled and having one apical broad and two sub-apical narrow white bands, mesonotum with hairs or narrow hair like scales

A fluviatilis (Fig. 5) —Small to medium sized comparatively dark mosquito, palpi with three pale bands, the dark band between the apical and sub-apical pale bands 4 to 5 times the length of sub-apical pale band Mesonotum pale medially, dark brown laterally Inner quarter costa continuosly dark; no fringe spot at V. 6, tarsi all dark or with very faint banding.

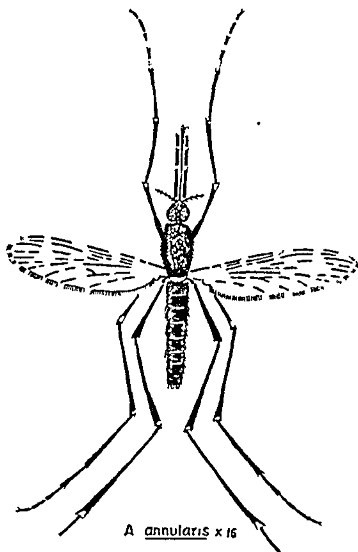
A minimus (Fig 6) —Closely resembles *fluviatilis*, but characterised by palpi with two broad apical pale bands, intervening dark band usually about as wide as either of the pale bands, rarely exceeding twice the extent of a sub-apical pale band. Proboscis mav be dark or have small flavescent area ventrally in the distal half Inner quarter costa with a pale interruption or an indication of this on at least one wing

A varuna (Fig 7) —Resembles *minimus* from which it can be differentiated by inner quarter costa without any pale interruption or any trace of it, distal half proboscis usually shows faint or sometimes marked flavascence

A jeyporiensis var *candidiensis* (Fig 8):—Small to medium sized mosquito, mesonotum covered with narrow whitish scales, base of anterior forked cell is slightly nearer the wing base than that of the posterior forked cell Wings with presector humeral pale spots, narrow pale apical bands on tarsi present There are three pale bands on palpi, the apical is broader than the other two pale bands In the type form the sub-apical black band is 4 to 5 times the length of the sub-apical pale band but in the variety *candidiensis* the sub-apical black band is equal or slightly broader than the sub-apical pale band

A leucosphyrus group (Fig 9) —Medium sized mosquito with narrow pale bands on palpi, proboscis dark, wings with multiple small dark spots on a number of veins, particularly V 3, V 5 and V 6, legs speckled, a wide white band at the tibio tarsal joint of hind legs, fore tarsi apically and basally banded, hind tarsi apically banded and tip of last segment pale

A culicifacies (Fig 10) —Small to medium sized mosquito with culex-like attitude when resting in living state, palpi are dark with narrow pale bands including that at the tip, mesonotum without scales, wings with a dark spot on V 1 under the pale interruption (humeral) on inner quarter of costa, V. 3 all dark, legs dark and tarsi usually unbanded



A annularis x 16

FIG 1

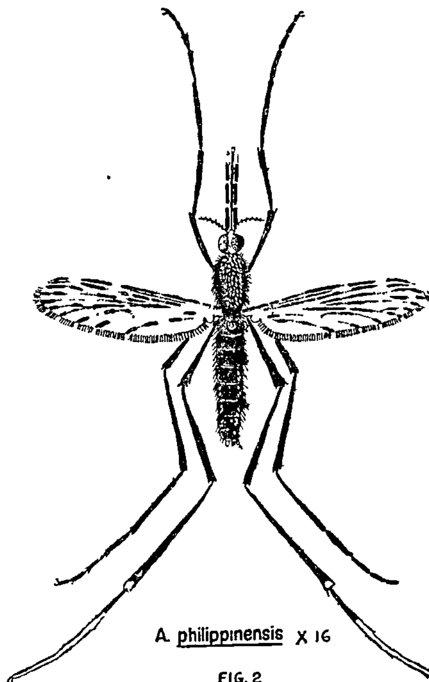
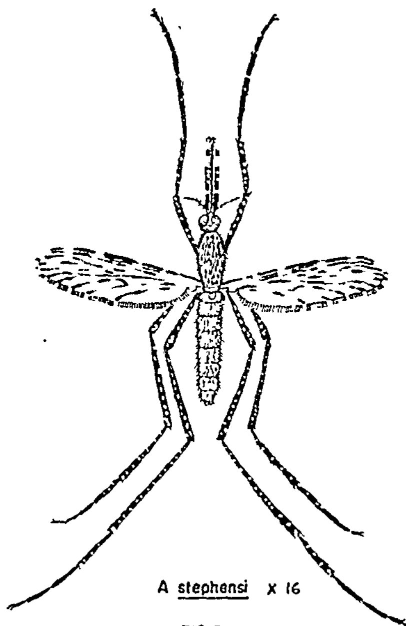


FIG. 2



A *stephensi* X 16

FIG 3

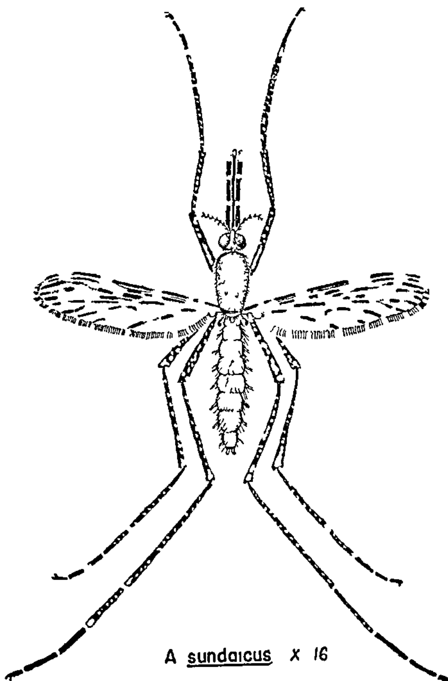
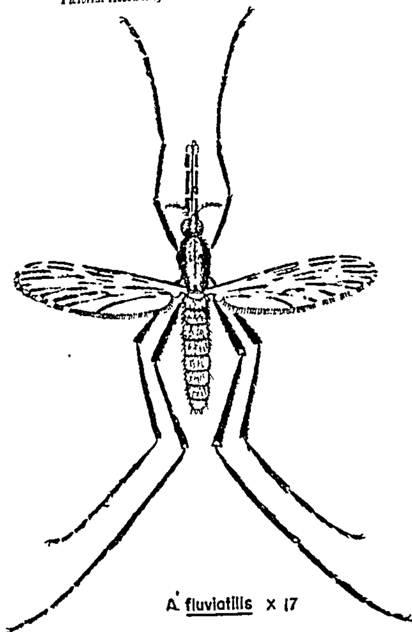
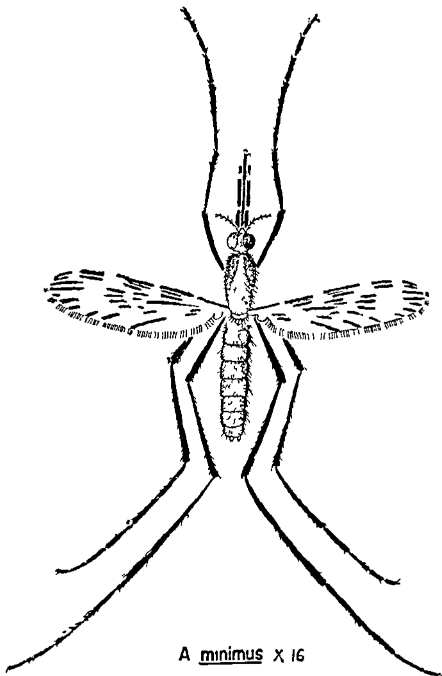


FIG 4



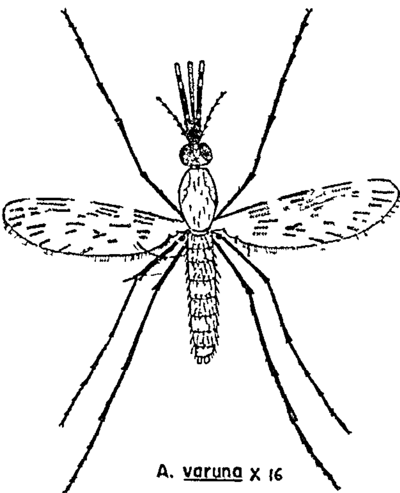
A. fluviatilis X 17

FIG. 5



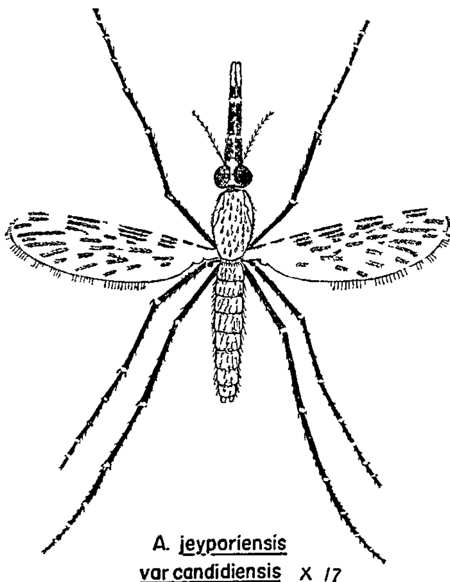
A minimus X 16

FIG 6



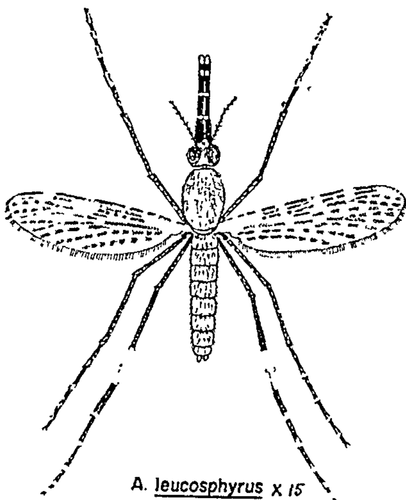
A. varuna X 16

FIG. 7



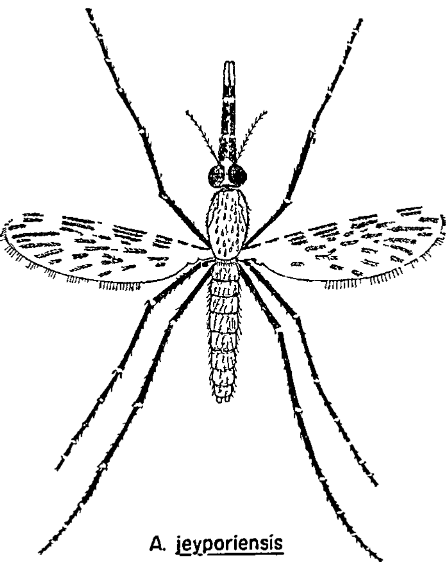
A. jeyporiensis var candidiensis X 17

FIG 8



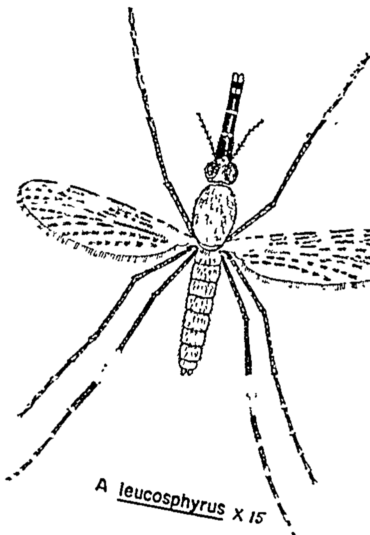
A. leucosphyrus x 15

FIG. 9



A. jeyporiensis var candidiensis X 17

FIG 8



A leucosphyrus X 15

FIG. 9

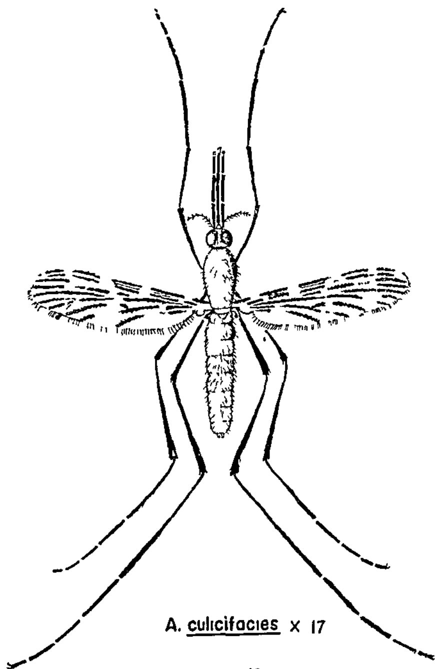


FIG 10

I. *A. ANNULARIS* VAN DER WULP, 1884

BY

V. VENKAT RAO

[*July* 7, 1954]

TILL about 1930, *Anopheles annularis* was known in India as *A. fuliginosus*. Its extra dark band on the apical segment of the palpi, was described in 1904 as variety *nagpori* while that with an extra dark band on the hind tarsus, giving only two segments continuously white as var *adiei* Both these are only melanic variations, the latter being usually seen as a winter form (Christophers, 1933).

Though *A annularis* is not important as a malaria vector in India as a whole, it has considerable local importance over a large area in the Orissa Coastal Plain, where it maintains hyperendemic conditions. In certain areas, it plays a secondary part in malaria transmission and is sometimes responsible for severe epidemic outbreaks

DISTRIBUTION

A. annularis has a very wide distribution in India[1] and in the Far East It is found almost everywhere in India, from Nepal in the north to Travancore in the south and from Assam in the east to Bombay in the west Outside India, it has been recorded from Pakistan (both east and west), Philippines, Formosa, South-China, Borneo, Java, Sumatra, Indo-China, Malay Peninsula, Thailand Burma, Ceylon and Little Sunda Islands

BREEDING PLACES AND HABITS

The preferred breeding places of A. *annularis* are clean weed-grown stagnant waters, notably margins of lakes, tanks, moats, dead rivers, swamps, borrow pits and ricefields Sometimes, it is also found in large canals with vegetation and in grassy edges of slow-running streams (Christophers, *loc. cit*) Studies by Sen 1941) and Senior White *et al.* (1943) in Bengal and Orissa respectively have shown that, while *A annularis* is capable of breeding

1 Chiefly in the plains but also in the hills up to 7 000 feet—*Editor*.

in a large variety of waters, the vast bulk of the breeding takes place in large weed chocked tanks, ponds and borrowpits on the one hand and in ricefields on the other Senior White found that borrowpits tanks and ricefields were responsible for 93 8 per cent of the total *annularis* output at Bhadrak and 98 4 per cent at Khurda Road Even where the tanks and borrowpits were clean-weeded at regular intervals as at the above two stations 67 per cent of the total larval output was found in them against about 27 per cent in ricefields

The tanks and ponds of Orissa and Bengal are overgrown with aquatic phanerogamic vegetation to a much greater extent than anywhere else in in India In Orissa Senior White and others identified from these waters 43 species of aquatic plants, not all of which were however, favourable for *annularis* breeding Working in Bengal, Sen (*loc cit*) observed that *Hydrilla verticillata* and *Ceratophyllum demersum* were especially associated with *annularis* In Orissa in addition to these two species *Nymphea lotus Nelumbium cristatum* and *Salvinia cacullata* had also been found associated with *annularis* On the other hand, certain plants like *Lemna minor Lemna polyrrhiza Wolffia arrhiza* and *Eichornia speciosa* were found unfavourable and even appeared to have an inhibitory effect The breeding in ricefields is often associated with the presence of filamentous green algæ mainly *Spirogyra* In hill tracts however, where tanks ponds and borrowpits are scarce, larvae are found in the grassy edges of slow running streams and rain-fed ricefields but their output is probably very low [2]

A annularis is mainly a fresh water breeder, but on a few occasions, Venkat Rao and Ramakrishna (1947) observed profuse breeding along the margin of the Chilka Lake in South Orissa, at a time when the salinity of the lake water was 600 parts per 100 000

Muirhead Thomson (1951) has shown that the temperature of stagnant waters like tanks and ricefields in Assam was about 41°C (106°F) at a time when the temperature of water in grass-edged streams seldom exceeded 34°C (90°F) The marked preference of *annularis* to stagnant waters, therefore, indicates that,

2 Borel (1926) in Indo-China found it breeding in tree holes and cut bamboos Walch and Soesilo (1927) recorded them in saline water in Java—*Editor*

the aquatic stages develop best in waters with a relatively higher temperature or at least that the flora favoured by them are present in quantity under such conditions

It may be stated in general that the breeding of *annularis* is profuse in areas with large bodies of stagnant water and vast stretches of ricefields, where these are limited, *annularis* is for all practical purposes insignificant

ADULT HABITS

Resting places —Quoting a number of observers Christophers (*loc cit*) concluded that in India *annularis* was pre-eminently a cattle feeding species being commonly found in very large numbers in cattlesheds and such like situations' Senior White *et al* (*loc cit*) also found the average ratio in human habitations and cowsheds as 1 3 They also observed that the maximum number in human habitations occurs frequently in August and September and the maximum in cowsheds in October and November and that the large autumnal production overflows into cowsheds more than into human habitations In cowsheds mad of thatched roofs with or without mud or bamboo walls *A annularis* rests to an appreciable extent in the inaccessible layers of the thatch and it has been found that in collections by hand only about two-thirds of the resting adults are captured The per-man hour collections made by hand catching are thus likely to yield only incomplete information about the actual *annularis* prevalence

The out door resting habits of *annularis* have been very little studied in India While working on out door resting anophelines Senior White (1946) was able to collect only one specimen of *annularis* resting on the bank of a stream but his observations were carried out in hill tracts where prevalence of *annularis* is negligible [3] More observations have however been carried out in Burma Tha Gyaw (1927) recorded that, from June to October, adults of this species could be found resting during the day in scrub jungle around their breeding places in Northern Burma Fox (1950) quoted Feegrade s observation that though adults could be seen feeding on cattle at night, there were none in human habitations or cowsheds during the day He also added his own observations that in the

3 Collected from among bushes Grass etc away from habitations (Christophers 1911)—Editor

Mandalay-Maymyo foothills, while 298 adults were captured in night collections, not a single specimen was found resting by day in human habitations These facts indicate that *annularis* in Burma rests more in outdoor shelters and is thus somewhat scarce in day time collections from either human habitations or cowsheds

Feeding time —The author's observations made in a student's hostel at Chatarpur (Ganjam District, Orissa) show that *annularis* enters the house for feeding during the second quarter of the night and that most of the feeding is completed before midnight Occasionally, however, they are found feeding at or shortly after sunrise

Food preferences —There is no doubt that *A annularis* is mainly a zoophilous mosquito Senior White (1947) dealing with Orissa Coastal Plain where *annularis* is a vector and the Central Provinces where it is not remarked that in both the areas the anthropophilic index is so low that *prima facie* it appears inconceivable that it should play any part in malaria causation The anthropophilic indices of house and cowshed resting specimens in these areas are shown in Table I

TABLE I

Anthropophilic indices of A annularis

Area	Houses			Cowsheds			Totals		
	No +	M +	A I	No +	M +	A I	No +	M +	A
Orissa Costal Plain	281	10	3 6	553	1	0 2	834	11	1 3
Central Provinces	148	3	2 0	466	8	1 7		11	1 8

M+=positive for man No +=number positive
A I =anthropophilic index per cent

Though precipitin tests were not carried out for *annularis* in Burma, night collections, as reported by Fox, were made while mosquitoes were actually feeding or about to feed, which tend to conform the Indian workers' observations on the zoophilic habits of this species

Fox (*loc cit*) concluded on the basis of available evidence that, under normal conditions, *annularis* feeds mainly on cattle and that,

if cattle are not available, it will readily feed on man He also quoted Macan as stating that *annularis* feeds on man-out-of doors too, if cattle are absent

Gonotrophic cycle —It was observed in a large number of cases that during July to November, when *annularis* prevails in large numbers, the gonotrophic cycle, is completed in 48 hours However, during the late rainy season and the autumn about 20 per cent of mosquitoes, are observed to require two or more feeds to mature a single batch of eggs The interval between the first feed and oviposition may in such cases extend to six or even eight days This condition, described as 'Gonotrophic disordance'[4] (Venkat Rao, 1947), has been observed also in *A culicifacies* in the Central Provinces The same condition has since been observed in *A fluviatilis* in South India by Jaswant Singh and Mohan (1951)

Swarming and mating —In India, despite the immense amount of work which had been carried out on the rich anopheline fauna up till about 1937, no observations had been made on swarming of Anopheles (Muirhead Thomson, *loc cit*) The first of such observations in nature were made in respect of *A annularis* and *A subpictus* by Ramachandra Rao and Russell (1938), which were followed by those on *A subpictus* by Venkat Rao *et al* (1942) Subsequently the present author observed swarming of males and females of *annularis* at Gangadharpur in Orissa, the same village where observations were earlier made on *sundaicus* and *subpictus* At the time, there was profuse breeding of *annularis* in the saline water of the Chilka Lake, whereas no such breeding was taking place elsewhere near the village as the ricefields had dried up and the fresh water tanks and ponds were under regular clean weeding and paris green treatment At about 5 30 p m (Indian Standard Time) in March 1946 a large swarm of mosquitoes was observed about six feet from the ground level not far from the Chilka Lake They were all *annularis*, both males and females Copulating pairs were also observed in the swarm Walking away from the Lake, the swarm was observed in an almost unbroken line for nearly half-a-mile, beyond which it gradually thinned out It will be *of interest* to note that *sundaicus* and *subpictus* swarms took place well away from

4 Senior White (1951) dealing with this phenomenon observed in a number of species *A aquasalis*, *A albitarsis* and *A neomaculipalpus*, and remarked that strict text book gonotrophic concordance appears to be the exception rather than the rule in several Anopheles.

the Lake, on the elevated platform of the railway station, which was at least 20 feet above the level of the Lake, whereas the *annularis* swarm was observed at a lower level of only five feet or so above the Lake and not beyond that altitude

Flight range —Christophers (*loc cit*) remarked that *annularis* "is a powerful flier', *covering considerable distance from its* breeding places and may be seen darting rapidly, when disturbed during the day, among bushes *etc*[5]

Hibernation —There is, of course, no true hibernation among Anopheles in India but, during winter, there is an appreciable reduction of *A annularis* density in Orissa,[6] though breeding places are still found in abundance However, the winter form with the extra dark band on the apical segment of the palpi is observed to come up in small numbers, not only in the Central Provinces where the temperatures are low in winter, but also in the Ganjam District of Orissa where the winters are very mild.

Longevity—Very little study has been made of the longevity of *annularis*, either under laboratory conditions or by field trials It is generally well known that, though all anopheline species are *potential* vectors many of them do not take any active part in transmission in nature because of their feeding habit lack of sufficient contact with man or inability to survive long enough to complete the sporogonic cycle Perhaps *A annularis* belongs to the last category However, Senior White *et al* (*loc cit*) calculated, by the relative prevalence of larvæ and adults, that the longevity of this species increases during September, October and the first half of November, when there is increased urge to feed on man and when only *infective specimens are encountered* On account of gonotrophic discordance observed by Vankat Rao (1947) the mosquito is fixed in houses (or cowsheds) for prolonged periods whereby it is not exposed to the natural hazards incidental to outdoor existence It thus appears that, in nature, *annularis* acquires greater longevity during September-November, than at other periods of the year.

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5 Anti larval treatment of breeding places situated within a radius of half a mile from the periphery of habitations can result in efficient malaria control among the inhabitants

6 *A annularis* is a winter species in Delhi State—*Editor*

RELATION TO MALARIA

A annularis is a vector of importance mainly in the Orissa Coastal Plain of the Indian region, where hyperendemic conditions are encountered. Though some infective specimen have been found in Bengal, they are not thought to be of real significance there owing to the more efficient vector, *A philippinensis* dominating the picture.* In the coastal plain of Orissa, Senior White *et al* (*loc cit*) dissected 9,183 specimens and found only 14 gut infections and 7 gland infections, giving a total infection rate of 0.23 per cent and a sporozoite rate of 0.08 per cent. They consider that transmission is possible under these conditions mainly because of the enormous density of this species, which is sometimes as high as 64 per man-hour in human habitations and 158 in cattlesheds. The presence of sporozoite infections as observed by Senior White *et al* (*loc cit*) is probably due to gonotrophic discordance, as such mosquitoes are not obliged to fly out frequently for oviposition and are fixed at the feeding place for prolonged periods. In areas however where climatic conditions are different from those in Orissa, and therefore gonotrophic discordance does not prevail *annularis* is harmless as a malaria vector. Outside the coastal plain *A annularis* with the sporozite rate of 0.08 per cent but with much lower densities is shown to be a secondary vector as in Puri Town (Orissa), where *A sundaicus* is the primary vector (Panigrahi, 1942). A few infections have also been found in this species around the Chilka Lake by Sarathy (1932) and on the North Madras Coast by Ramakrishna (Senior White *et al* 1947) but it is thought that *annularis* plays a minor and not very significant part in transmission there. In these areas it always exists along with *A sundaicus*. Severe epidemics are sometimes found superimposed on hyperendemic conditions in the Coastal Plain as well as in those restricted localities in the same area where there is a milder degree of malarial endemicity. These however, are localised and occur at irregular intervals of five to seven years.

According to Fox (*loc cit*) *A annularis* is an important vector on the Arakan Coastal Region of Burma; out of 1,315 specimens dissected from that region three gut infections and seven gland

* *Annularis* has also been recorded as a vector in Assam by Viswanathan. Infective specimens of *annularis* have been reported by Dr [illegible] in [illegible] (U. P.) during August and September 1951 [illegible] also reported infective specimens from [illegible] (1953) has

infections were found, giving an infection rate of 0 07 per cent and a sporozite are of 0 05 per cent These infection rates are lower than those recorded in India but there too transmission is probably dependant upon heavy densities of the vector In this region also, *annularis* co-exits with *A sundaicus* but curiously enough no infections were found in the latter species and, therefore, *annularis* has to be considered as the major vector, with *A sundaicus* playing a secondary part Fox also quotes Robertson as recording six 'infections' out of 392 dissected (infection rate 1 5 per cent) on the Burma-China border in Western Yunnan, where *A minimus* is the principal vector [8]

CONTROL

Anti larval measures against a prolific breeder like A annularis are likely to be very difficult in rural areas As the breeding occurs in both weed choked stagnant waters and in ricefields, chemical larvicides like oil and paris green are liable to be very costly and, sometimes owing to unfavourable weather conditions, ineffective as well Biological measures like clean-weeding were tried on a large scale by Senior White *et al* (1943) and Venkat Rao and Ramakrishna (1947) and observed to be effective against *annularis* but they were tried at a time when labour was cheap enough to compare favourably with chemical treatment At present, owing to greatly increased cost of labour, such measures are not likely to find favour with either malariologists or administrators Paris green treatment of ricefiels is beset with difficulties, not the least of which is the oppositions from rice growers who are perhaps needlessly afraid of damage to the crop Venkat Rao (1942) has shewn that *annularis* breeding in ricefields can be effectively controlled by stocking them with sullage during the dry season (or by a liberal use of organic manures like compost) but this presupposes a high level of agriculture which is yet to be attained

As the transmission is restricted to four months only from August to November each year, the best method of control would be to spray all houses and cowsheds with DDT at the rate of 100 milligrammes per square foot in a single dose during June July The *per capita* cost of such spraying does not exceed six to eight annas,

8 Tyssal Jones (1950) considers *annularis* as the principal vector in Kyankpyn Ramree island in Burma—*Editor*

which is well within the financial capabilities of any community [Effective control of this species by DDT residual spray has been obtained in mud plastered houses in Orissa (Hajra 1948 Adhikari and Ganguli 1949) The dosage used was 38 50 mg per sq ft and its residual effect lasted for 6 8 week —*Editor*]

In large towns like Cuttack and Berhampur where the population is high and breeding places are relatively limited clean weeding of stagnant waters coupled with improved methods of rice culture specially in the immediate vicinity of towns is l kely to result in effective control of malaria there It is realised that these towns are not endemic for malaria but are subject to periodical epidemic outbreak however, continued work specially in the inter epidemic periods may be found to be advantageous in warding off and even eliminating such outbreaks

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II. *A PHILIPPINENSIS* LUDLOW, 1902

BY

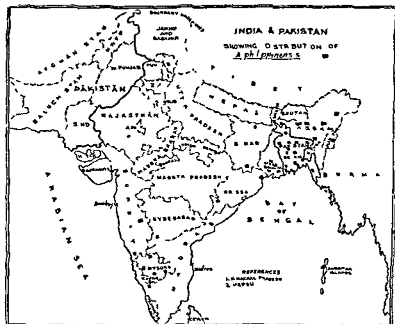
K S. KRISHNAN

(*Malaria Institute of India, Delhi*)

[June 6, 1953]

DISTRIBUTION

A philippinensis has a wide distribution in the Indian subcontinent (Map 1)—Assam, Bengal, Bihar, Bombay, Deccan Konkan, Madras Coast North, Malabar, Mysore, Orissa, and Andamans Outside India it is found in Burma, Thailand, Indo China, South China, Sumatra, the Philippine Islands, Borneo and New Guinea.



Map 1

BREEDING HABITS

The favoured breeding places of *A philippinensis* are tanks, pools, and ditches, Christophers (1912) and Covell (1927) found this species breeding in ricefields in the Andamans Sen (1935, 1948 *a* and *b*) recorded *philippinensis* breeding in ricefilds in Bengal

but the numerical incidence was low He attributed this restricted breeding in ricefields to two factors (a) the absence of green algæ—Spirogyra—from ricefields due to increase in shade when the rice plants grew to a height of 2½ feet and postulated a very close association between *philippinensis* breeding and Spirogyra, (b) it was also found that the temperature in ricefields reached 42°C or more and it was beyond the tolerance limit of the species But Krishnan (1940) in Bengal found no larvæ in ricefields Iyengar (1944) too did not find any larvæ of *A philippinensis* in ricefields in Mymensingh Breeding in borrowpits in Bengal was practically negligible (Iyenger, 1944)

Ramsay and Macdonald (1936) found *philippinensis* breeding in permanent pools with vegetation and light shade Iyengar (1944) reported that this species liked ponds exposed to sunshine containing water with high dissolved oxygen content and bred in clean waters and were absent in waters even with the slightest trace of sullage or organic contamination Intense breeding was found to take place in water with thick growth of submerged vegetation particulary *Hydrilla verticillata* *Ceratophyllum demersum* and certain species of Utricularia and Najas Duckweeds and water hyacinth were not suitable for they cut off sunlight and thereby brought about changes in plankton in the water Certain types of green algæ which thrived well in sunlight were favourable to the breeding whilst certain other algæ like Cyanophyceæ and the blue green algæ (*e g* Anabæna and Oscillitoria) were inimical Euglena was also unfavourable There was such close association of breeding of this species and the type of vegetation which made Bose (1931) bold to state he could attract or repel this species from village tanks by introducing or removing suitable vegetation The prevalence of *philippinensis* is dependent on the depth of subsoil water (Iyengar 1942) He found that if the level of the water table is low the density of the species is high and *vice versa* The seasonal prevalence of this species in Bengal is July to October (Iyengar 1944)

BIONOMICS OF ADULTS

(a) *Adult resting places*—In Bengal *philippinensis* has been found resting mostly in human habitations (Timbers 1935 Krishnan 1940 and Iyengar 1944) Ramsay and Macdonald (1936) found in Assam the adult resting in equal numbers in cattlesheds and houses

while in Bengal the preference was more to the houses Ganguli (1947) found in Bengal-Orissa border (between Balrampur and Ruspa) that adults were resting only in houses and in two years search no specimen was collected in cattlesheds while the number collected in houses was 276

Iyengar (1944) found that the adults usually rested on the wall within 1½ feet of the floor inside houses Ganguli (*loc cit*) could not confirm this finding but observed that *A philippinensis* rested in the day time on the walls of dark room from about four feet above the floor, hanging clothes umbrellas, *etc*, and were not found too near the floor Reid and Wharton (1949) in Malaya found 454 *philippinensis* adults resting out of doors during day time in a rubber estate in a total collection of over 1,600 anophelines

BITING TIME

In Bengal, the adults were mostly noted to feed from 8 to 10 p m and 2 to 4 a m In Malaya, they were found to feed throughout the night and the majority did not commence feeding until after 9 p m (Reid and Wharton, 1951) Wharton (1950) observed that *philippinensis* entered huts after 9 p m After feeding they went to the grass outside the sheds and many of them rested there till dawn Macan (1950) in Arakan region reported that this species attacked people out of doors He also observed that *A philippinensis* showed a small biting peak round about midnight and a main peak between 03 00 and 04 00 hrs The same author (Macan, 1948) while working in the Rabaw and Kale valleys in Burma found the peak of biting intensity between 22 30 and 23 00 hrs and thereafter a marked falling off, a second peak between 01 00 and 01 30 hrs and biting continued at a reduced rate from then until dawn

ANTHROPOPHILIC INDEX

The precipitin tests carried out are very few and the only published records are from Assam by Ramsay and Macdonald (1936) where the anthorpophilic index noted was 6 4 in 343 specimens tested, and in Malaya the index was zero per cent in a test conducted on adults caught from outdoors (Reid and Wharton, 1949)

FLIGHT RANGE

No information direct or indirect is available regarding the flight range

SURVIVAL OR LONGEVITY

Green (1934) reported that the mean survival time of A philippinensis in Malaya was 48 days with a range of 4 62 days, under laboratory condition

SWARMING

Swarming of A philippinensis was regularly observed in Malaya It commenced 10 15 minutes before complete darkness and followed normal patterns except that swarming site did not appear to bear any relation to specific objects such as bushes (Reid and Wharton, 1949)

RELATION TO MALARIA

A philippinensis is a very important vector in Deltaic Bengal Natural infection of this species has been reported from Burma but it is not considered an important carrier there The dissection records so far available are given in Table I

Iyengar (1940) reported that the infection rates were high during the period September to January and no infection was found during March and April The high infection rates recorded during the period September to November conform to the generally accepted view that transmission of malaria in Bengal is most frequent following the monsoon Sen (1948 b) stated that transmission period was June to December and the maximum was in August and September Ganguli (1947) found both gut and gland infections during August and October

CONTROL

Anti adult —The information so far available goes to show that A philippinenss is susceptible to insecticide sprays The published report regarding the control of this species by residual insecticides are very meagre except for Nasiruddin (1952) who stated that in Gubtali in E Pakistan, A philippinensis disappeared entirely from the treated places and the treated walls remained lethal for nine months The dosage he employed was 106 mgs per sq ft

Anti larval—The naturalistic methods advocated by Iyengar (1944) for the control of breeding of A philippinensis are (1) covering the water surface with a dense growth of water hyacinth but it raises problem of its own As complete cover is not possible this

TABLE I

Dissection results of A philippinensis

Observed	Area	Number dissect-ed	Gut infection	Gland infection	Total infection	Per cent infection	Remarks
Feegrade, 1926	Bhamo, Burma	189	2	1	3	16	
Sur, P , 1928	Bengal	223	3	5	7	3 1	
Sur and Sur, 1929	Krishnagar, Bengal	770	—	15	15	2 0	
Strickland, 1929	Cachar, Assam	2,410	0	0	0	0	
Ramsay, 1930	Cachar, Assam	6,895	0	0	0	0	
Sweet, 19293 0	Mysore, South India	17	0	0	0	0	
Timbers, 1935	Bengal	12 594	—	—	—	1 4	
Ramsay and Macdonald, 1936	Assam	12 466	0	0	0	—	
Toumanoff 1936	Tokin (1931-33)	592	0	0	0	—	
Niogi and Khan, 1937	Bengal Dooars	101	—	—	2	—	
Iyengar, 1939	Bengal	1,918	81	76	—	7 2	Sporozoite rate 4 0 Number with both gut and gland infection-139
Iyengar 1940	Bengal	1,830	68	65	—	6 3	Sporozoite rate 3 9 Number with both gut and gland infection-116
Viswanathan *et al* , 1941	Assam (1931-1941)	4,239	2	2	4	—	
Sen, 1948 *a* and *b*	Madhagram, Calcutta (1936)	180	0	—	12	6 6	
Macan, 1948	Kabaw and Kale Valleys Burma	505	0	0	—	—	

often gives rise to intense culicine breeding, (2) complete removal of vegetation and (3) introduction of water into the area to raise the water table—wet cultivation to be encouraged He also considered that drainage was not a suitable measure to control the breeding of *A philippinensis* in Deltaic Bengal

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III. *A STEPHENSI* LISTON, 1901

BY

K S Krishnan

(*Malaria Institute of India, Delhi*)

[October 2 1953]

The possible existence of two races of *A stephensi* was thought of at various times (Knowles and Basu, 1934, Mulligan and Baily 1936 Ramsay and MacDonald, 1936) Sweet and Rao (1937) were able to show significant differences in the eggs (Appendix 1) and classified the species into two races—*A stephensi* type and *A stephensi* var *mysorensis* They also showed that the two races differ in their adult habits The varietal form is less hardy than type form more zoophilic and difficult to colonise As few records are available where this species has been treated as two races, for purposes of this review both the races have been dealt with as one species but wherever it has been possible they have been discussed separately Viswanathan (1950) regards type form as inhabitant of urban areas and the var *mysorensis* of the rural areas

DISTRIBUTION

A stephensi is widely distributed in India (U P, Punjab, Delhi, Saurashtra Madhya Pradesh, Bombay, Hyderabad Madras Bengal, Bihar, Mysore Assam and Kashmir (vide map 2) Outside India, it is found in N W F P, Waziristan Sind Burma and China Its distribution extends westwards through Bahrein Islands, Iran and Iraq to E Arabia It has not been recorded from Ceylon, the Andamans, nor has it been found in Malaya

BREEDING PLACES

A stephensi, in the urban areas, breeds in wells, cisterns, fountains, ornamental tanks artificial containers and in waters used for keeping the surface of cement concrete wet during building construction In rural areas, it is found, breeding in pools, in stream beds and at the margin of stream itself, in seepages and marshy areas with a gentle flow of water, irrigation channels, reservoirs and springs, showing a preference to sunlit breeding places (Mulligan and Baily, *loc cit*) In Bahrein, the larvæ were found in

INDIA

SHOWING DISTRIBUTION OF A STEPHENSI

AREAS WHERE THE SPECIES OCCURS 

AREAS WHERE THE SPECIES IS A VECTOR 

AFGHANISTAN
PAKISTAN
TIBET
PAKISTAN
BURMA
ARABIAN SEA
BAY OF BENGAL
Bombay
Madras
ANDAMAN ISLANDS
CEYLON

drains shallow wells and garden pits containing seepage water The upper limit of salinity in which larvæ were found was 2 750 *parts* per 10 000 (Afridi and Majid, 1938) In Bombay this species has been found breeding in water with high salinity sometimes reaching or even exceeding that of sea water (Bently 1911 Chalam 1926 Bana, 1943) In Iraq *A stephensi* did not breed readily in localities which have high salinity or which are shaded by over hanging or emergent vegetation Grassy depressions and pools yielded very high numbers of larvæ They were rare in large expanse of water and abundant in small pools (Macan 1950) Roy (1931) in Calcutta found that this species could tolerate water with high degree of organic pollution and found breeding in drains contaminated with sewage Russell and Mohan (1939) successfully reared *A stephensi* larvæ in the laboratory in sullage water containing upto 50 parts per million of ammonia nitrogen It breeds equally well in places exposed to direct sunlight and in dark places Its larvæ have the power to sink deep and to remain there for long periods before reappearing at the surface

ADULT HABITS

Resting places—There are conflicting views regarding the resting habits of *A stephensi* In Mesopotamia Christophers and Shortt (1921) found that this species is of retiring habit and its presence therefore, is not easily detected Macan (*loc cit*) is also of the same view In Calcutta, Knowles and Basu (1934) experienced difficulty in capturing adults in dwellings in spite of the species breeding in large number throughout the city Ganguli (1935) also found this species very scarce in Calcutta Strickland *et al* (1936) during one year s survey were able to collect 273 specimens of *A stephensi* out of a total of 8 564 anophelines among the former only a few were noticed to have taken a blood meal Senior White (1940) concluded that the day time resting place of the species is obscure in Calcutta Mulligan and Baily (1936) in Quetta found that *A stephensi* showed a marked preference for resting places in close proximity to human and animal dwellings Out of 1 200 specimens of *A stephensi* 1 119 were collected from human habitations or from situation in their immediate vicinity In Quetta *stephensi* rested by day close to where it fed at night. It was rarely found in outdoor resting place Afridi and Majid (*loc cit*) in Bahrein Islands came to the conclusion that *A stephensi* selects its

day-time resting places in houses situated in the vicinity of its breeding grounds but that it makes daily incursions into the interior of the town in search of food Subba Rao and Appa Rao (1945) in Vizagapatam found that this species was rare in pukka houses but plentiful in thatched huts and cattlesheds Rao *et al* (1949) collected easily large numbers of adults from inside dwellings in the ceded districts of Madras In a total collection of 3 885 *stephensi* adults 18 per cent were found in human dwellings, 32 per cent in cattle sheds and 50 per cent in mixed dwellings Adults when resting indoors are usually found on palm leaves hanging vertically from the roof on men s kits especially leather belts, haversacks *etc* and under the projecting eaves of huts It has also been observed in ceded districts of Madras that *A stephensi* showed marked preference for vertical surfaces a common haunt being the junction of walls and ceiling Attics used for storing fodder yielded a good number of this species (*Rao et al*, *1946*)

Biting time —No experimental work has been done on the biting time of this species It is presumed that it commences to bite at dusk or soon after DeBurca and Jacob (1947) found *A stephensi* feeding in the open at 0900 hours They also observed that in early afternoon while sitting in rather a dark office it bit in numbers Nursing *et al* (1934) in Mysore used a tent with human bait and made collections at 9 p m and midnight and again at 4 a m and 6 a m in the morning In 9 p m and midnight catch *A stephensi* formed 33 0 per cent of the catch and between 4 and 6 a m it was 67 per cent The condition of the mosquitoes was not noted and hence it was difficult to assess the biting activity In Baghdad, certain observations in 1941 showed that biting time of *A stephensi* was over by midnight (Ramakrishnan, 1953)

Food preferences —Sweet and Rao (1937) stated that the type form feeds avidly on man Roy *et al* (1938) found by precipitin test that 3 4 per cent had fed on man and 96 6 per cent on cattle in a total of 172 samples tested Afridi *et al* (1939) found 1 4 per cent of *A stephensi* with human blood in a series of 360 positive precipitin test Senior White (*loc cit*) stated that in Calcutta both the *races are attracted to cattle rather than to man* Barber and Rice (1938) in Poona found no human positive in 43 positive precipitin tests Rao *et al* (1946) found the anthropophilic index of *A stephensi*

to be o 8 per cent in a total positive precipitin reactions of 75 69 1 per cent had fed on cow

A series of precipitin tests of blood meals of *A stephensi* were carried out in the laboratories of the Malaria Institute of India In Bellary area the anthrophilic index was 11 0 per cent while 26 per cent were positive with bovine serum out of 118 tested In Munirabad area (Hyderabad State) out of 24 blood meals tested 41 per cent gave positive reaction with human serum (October 1949 —February 1950) The anthrophilic index in Ajmer area was as high as 47 per cent in a total of 201 blood smears tested (April 1950, Malaria Institute Report 1948 1950)

Flight range —Covell (1944) surmised that in urban areas this species has a flight range of ½ mile In rural areas it can fly a distance up to 3 miles Russel *et el* (1943) In Bahrein Islands Afridi and Majid (1938) found this species resting in huts 1½ miles away from the nearest breeding place and thus assumed that distance to be the flight range

Seasonal prevalence —The peak of *A stephensi* breeding in Calcutta occurs in July and thereafter rapidly falls until December (Knowles and Basu 1939) In Quetta this species was more prevalent from July to September and then there was sudden fall towards the end of September and by early part of October adults of *A stephensi* were extremely scarce (Mulligan and Baily *loc cit*) In Iraq *A stephensi* had two marked seasons in May and June and in October and November and in the intervening months it was scarce (Macan *loc cit*) In ceded districts of the Madras State Rao *et al* (1946) found that the peak months for this species were from November to March

Hibernation —Mulligan and Baily (*loc cit*) stated that in Quetta *A stephensi* probably did not overwinter in the adult stage Adults of *A stephensi* showed a marked decline in numbers towards the cold months In Iraq there was no evidence of hibernation and the species probably bred throughout the year and the numbers became reduced during the cold weather (Macan *loc cit*)

Swarming and mating —Swarming and mating of *A stephensi* has not been observed in nature Russell and Mohan (1939*a*) have described the swarming and pairing of the species inside a

colony cage and it would be of interest to read the original article Rao *et al* (1938) had no difficulty in colonising *A stephensi* type even in small cages but *A stephensi* var *mysorensis* resisted all attempts at colonisation and no generation beyond F_1, could be obtained Senior White (loc cit) observed that the fertility of var. *mysorensis* in captivity was very low But Russell and Mohan (1941) successfully colonised var *mysorensis* through nine generations

Longevity —Knowles and Basu (1943) carried out studies on the infectivity of *Anopheles stephensi* During these studies they kept mosquitoes alive under controlled conditions of temperature and humidity after giving one blood meal and later fed on fruit juice and water They came to the conclusion that the death rate increased at high temperature At 100°F, none survived long enough to become infective In their words "At temperatures between 50°F and 80°F a high degree of relative humidity does not seem to be essential for the longevity of *A stephensi* as long as sufficient food and water are provided, but at higher temperatures this factor becomes of great importance." The percentage of survivors of this species was found to be highest at low temperatures and with higher percentage of humidity

RELATION TO MALARIA

This is an important vector under rural conditions in Western and North Western India, the Persian Gulf and under urban conditions in certain localities (Bombay Bangalore and Lucknow).

A stephensi mysorensis was considered less important as a vector than the type form but Senior White (*loc cit*), and Subba Rao and Appa Rao (*loc cit*) have shown it to be the chief rural carrier in Vizagapatam Natural infections recorded in this species (both races) are given in Table I.

City of Bombay had a severe epidemic of malaria in 1901 It was due to *A stephensi* establishing itself to breeding in wells and cisterns throughout the city, an unusual adaptation which this species alone has shown (Christophers, 1949)

A stephensi has caused severe malaria epidemics in certain areas In the year 1929, Lucknow city had a major malaria epidemic which was quite peculiar in that it was during late spring (April—September) instead of in the autumn as usual in this part of

India *A stephensi* was solely resposible for causing this epidemic and the infections were predominently of benign tertian The mortality rate due to fever in the month of May was as high as 6 05 per 1 000 (Banerjea 1930)

In September 1941, when troop concentration commenced in and around Baghdad there was a sharp epidemic of malaria which affected the troops as well as the local urban and rural populations The only mosquito found infected was *A stephensi* The epidemic was quickly brought under control by space spraying with pyrethrum everyday for about four weeks (Ramakrishnan *loc cit*)

CONTROL

For the control of urban malaria transmitted by *A stephensi* Covell (1949) recommended the provision of a continuous high pressure supply of filtered water in order to do away with the necessity of storing water on premises and wells and cisterns to be made mosquito proof This species is very susceptible to DDT Effective control with this insecticide has been obtained by Afridi and Bhatia (1947) Viswanathan (1950) and Adhikari and Ganguli (1949) The dosage used ranged from 25 to 50 mg per sq ft

A STEPHENSI AS A USEFUL LABORATORY INSECT

A stephensi is a good laboratory insect It colonises easily in small cages it adjusts itself to varying larval and adult environments and feeds equally well on man and other animals and is highly susceptible to experimental infections Russell and Mohan (1939*b*) suggested that *A stephensi* may be used as a measuring rod to gauge the significance of experimental infections in other species in India

A stephensi has also been found susceptible to experimental filarial infections of *mf bancrofti* and not of *mf malayi* (Rao and Iyengar, 1932 and Raghavan and Krishnan 1949) This insect therefore, may sometimes be conveniently used for xenodiagnosis in human filarial infections

DISCUSSION

Roy *et al* (1938) expressed doubts regarding the classification of *A stephensi* into two biotypes They agree that variations in size of o a ex st, but they do not agree with the view that the type form carries and the other does not carry malaria This point they

have discussed in the light of the precipitin tests conducted by them in Calcutta To quote them ' The fact that only three out of a hundred specimens of *stephensi* which were subjected to precipitin test were found to have fed on man is a matter that needs serious consideration and indicates that the natural inclination of this species is to divert its attention to animals in the stable rather than to human habitations The findings of Senior White (*loc cit*) and Subba Rao and Appa Rao (*loc cit*) also go to show that the varietal form is an efficient vector As regards the behaviour of these two races in captivity Russell and Mohan (1941) have shown that they could colonise *A stephensi* var *mysorensis* adopting special technique Sweet *et al* (1938) tried cross breeding of these two races and reported that ' there would seem to be quite a definite natural barrier to successful cross breeding between types B and M, since with crosses in both directions only a small minority of the females laid eggs and a still smaller minority laid viable eggs From the viable eggs of the very few cross mated females laying it was possible to raise successive generations of hybrids but in each generation there were instances of the laying of sterile eggs ' It would be necessary to have more information on this point to interpret the cross breeding of the two races

From the above remarks it seems necessary that these two races have to be studied in more detail and it is imperative wherever possible to mention the particular race of *stephensi* one is encountering Without this the knowledge of distribution of these two races is very imperfect Covell (1944) mentions that var *mysorensis* has been reported to occur in Poona Sind Mysore State (not Mysore City or Bangalore) Vizagapatam and he believes that it might have a wider distribution It is not known if var *mysorensis* occurs outside India

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TABLE I

Infections recorded in A Stephensi

Observer		Locality	Number dissected	No of guts infected	Oocyst rate per cent	Number of glands infected	Sporozoite rate, per cent	Remarks
1		2	3	4	5	6	7	8
Liston	(1908)	Bombay						Per cent infection 25 0
Bently	(1911)	Bombay	1 228	91	7 4			
Total 1909-1911		Bombay	1 217			30	2 4	
Hodgson	(1914)	Delhi	110	2	1 8			
Sinton	(1917)	Kohat	45			1	2 2	
Mayne	(1928)	Saharanpur	248	0				
Banerjea	(1930)	Lucknow	75	7	9 3	5	6 7	
Chalam	(1927)	Bombay	151	2	1 3	5	3 3	Per cent infection 4 6
Covell	(1928)	Bombay	671	17	2 5	12	1 8	
King and Iyer	(1929)	Mopad Madras	166	9	5 4	1	0 6	
Sweet and Rao	(1931)	Mysore State	2 710	2	0 07			
Abraham	(1932)	Hyderabad	153					Per cent infection 3 5

(*Continued*)

Narsing Rao and Sweet (1934)	Mysore State	277	3	1.1			
Covell and Baily (1934)	Khairpur State Sind	250	6	2.4			
Mulligan and Baily (1936)	Quetta	719	5	0.7	2	0.3	Mid Aug.—Mid Sept
Afridi, *et al* (1938)	Kutch State	238	2	0.8	3	1.3	Per cent positive 1.0
Afridi and Majid (1938)	Bahrien Islands	1,142	8	0.7	1	0.08	Per cent positive 0.7
Senior White and Venkat Rao (1943)	Vizagapatam	225	6	2.7	4	1.8	Infections in var *mysorensis*
Jaswant Singh and Jacob (1943)	Ahmdabad						Per cent positive 1.4
Subba Rao and Appa Rao (1945)	Vizagapatam *Urban*	338		0.26		2.6	Sporozoite rate for *type* 6.9
	Rural	304		1.3		1.3	Sporozoite rate for *mysorensis*—2.4
Siddons (1946)	(Sept 1942 Oct 1944) Calcutta (1943 45)	1,052	4 out of 678 guts	0.58	6 out of 1,052 glands	0.56	4 out of 9 specimens were definitely of type form Transmission season July to late Sept
Rao R B *et al* (1946)	Ceded Districts Madras State	902	1	0.1	1	0.1	
DeBurca and Jacob (194-)	Fort Sandeman	152			1	0.65	
Godbole *et al* (1948)	Bijapur	1,272		·	1	0.08	*Infection in var mysorensis*
Macan (1950)	Shat al Arab Iraq (By Warson and Newman)	289	1	0.3	2	0.7	Total infection 1.0 per cent
	Baghdad area (by Ramakrishnan)	287				0.35	
Viswanathan (1950)	Nira Canal *Zone* Sholarpur District, 1948 49	3,450					Per cent positive 0.93

APPENDIX I

Mean egg measurements of two forms of A Stephensi

SWEET, RAO AND SUBBA RAO (1938)

	Length (Microns)		Breadth including floats (Microns)		Length of float (Microns)		Number of ridges on one side of float		Proportion of length covered by the floats	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
A stephensi	555 ±0 30	24 ±0 30	204 ±0 15	12 ±0 11	294 ±0 20	23 ±0 20	18 ±0 20	1 6 ±0 01	0 53 ±0 0004	0 03 ±0 0003
A stephensi var mysorensis	476 ±0 20	24 ±0 14	106 ±0 10	12 ±0 07	218 ±0 17	20 ±0 12	13 ±0 01	1 2 ±0 007	0 46 ±0 0003	0 03 ±0 0002

IV. *A SUNDAICUS* RODENWALDT, 1926

BY

V VENKAT RAO

[*December 7 1905*]

A Sundaicus is the only member of the *ludlowi* group of anophelines which has been recorded in or near India Till King (1932) classified the various members of this group as distinct species identifiable by morphological differences among the adults *A sundaicus* was referred to as *A ludlowi* by Indian workers It may be emphasised that the latter species has a very limited distribution and does not occur in India It is recorded with certainty only in the Philippine Islands and possibly also in Formosa

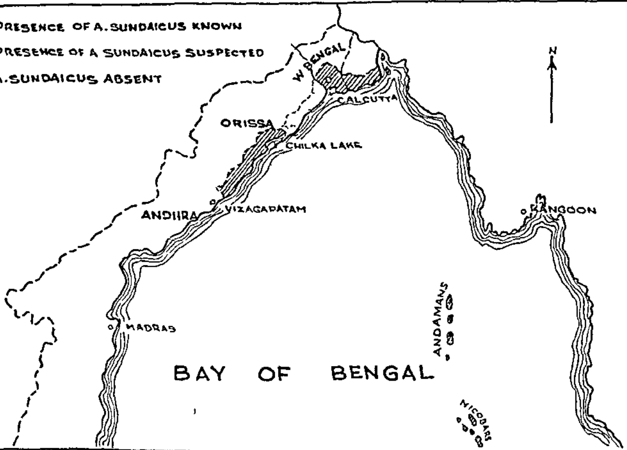
DISTRIBUTION

In India *A sundaicus* has been found only in the coastal areas of West Bengal Orissa and North Vizagapatam District Even in these areas, the distribution is somewhat patchy and not always continuous While, in West Bengal there is a fairly uniform distribution up to about twenty miles southwest of Calcutta, there is yet no evidence of the presence of this species further south or in the 200 miles length of the sea coast between Puri and the Bengal border in Orissa itself The southernmost limit of *sundaicus* prevalence is the Vamsadhara River in the North Vizagapatam District Besides these areas *A sundaicus* is also recorded in the Andaman and Nicobar Islands in the Bay of Bengal (Map 3)

Outside India the distribution is much wider and embraces practically the whole of the oriental region *viz* East Pakistan, Burma Thailand, Indo China South China Malaya Great and Little Sunda Island and as far east as Rcma (Covell 1944)

BREEDING PLACES

A sundaicus is well known for its close association with coastal conditions and its preference for breeding in brackish waters The species breeds pre-eminently in salt swamps c llections of brackish water behind coastal bunds and such like situations (Christophers, 1933), but not in waters subject to the influence of daily tides or in virgin mangrove (Covell, *loc cit*) In the Calcutta area larvæ of


PRESENCE OF A. SUNDAICUS KNOWN
PRESENCE OF A SUNDAICUS SUSPECTED
A. SUNDAICUS ABSENT
N
W BENGAL
CALCUTTA
ORISSA
CHILKA LAKE
ANDHRA
VIZAGAPATAM
MADRAS
RANGOON
ANDAMANS
NICOBARS
BAY OF BENGAL

sundaicus are found mostly in standing waters like lakes, tanks and ponds and in large railway borrowpits. In Orissa, the main breeding place of *sundaicus* is the Chilka Lake, which is over 500 sq miles in extent In addition, considerable numbers of larvæ are found in tanks, ponds and railway borrowpits containing fresh or saline water, and occasional breeding may also be found near the mouths of rivers and in ricefields situated along the margin of the Chilka Lake The breeding places in the North Vizagapatam District are almost exclusively tanks, ponds and borrowpits containing fresh water.

Outside India, except in Sumatra,[1] *A sundaicus* is everywhere a brackish water breeder. There was a fresh water form of *sundaicus* —a potent vector—in Sumatra breeding in fresh water fish ponds but it was eliminated when the breeding places were eradicated (Bonne Wepster and Swellengrebel, 1953) Covell (*loc cit*) refers to the presence of fresh-water *sundaicus* in the narrow valleys among the mountains running parallel to the west coast of Sumatra, at a height of 1,500 to 3,250 feet above the sea level

The brackish water form, which is more commonly met with, breeds extensively in moderately saline waters In Orissa, Covell and Singh (1942) found the optimum salinity of its breeding places to be from 600 to 800 parts per 100,000. Senior White and Adhikari (1939), working earlier in the same area, concluded that the optimum salinity was 869 parts per 130,000, while the inhibitory salt value was 2,300 parts They, however, found scanty breeding in waters with salinity higher than 1,300 parts. On the other hand, Christophers (1912) found the optimum salinity in the Andamans to be 400 parts and Iyengar (1931) in Bengal 150 to 250 parts per 100 000[2]

Working in Puri Town Panigrahi (1942) observed larvæ in waters with salinities lower than 100 parts in fact, he did not find

1 In S[illegible] te breeding places of [illegible] ithout vegetation and [illegible] gin of streams during [illegible] rice fields in a lesser [illegible]

2 [illegible]

sundaicus breeding in brackish waters at all, though such waters exist there in good numbers Pursuing their studies in the Chilka Lake area, Senior White *et al* (1947) found larvæ at practically all salinity values below 2,300 but came to the conclusion that, in that area, larvæ were more likely to be found in fresh than in saline waters but the output from the latter, particularly from those with values between 700 and 800, was much higher.

The breeding places in the North Vizagapatam District, as already stated, are mostly fresh waters, with salinities well below 100 parts per 100,000

Many Indian workers have also observed the close association of *sundaicus* larvæ with certain types of aquatic vegetation Senior White and Adhikari (*loc cit*) observed that the favourite breeding place of *sundaicus* in the Chilka area was among the putrefying masses of sub aqueous plants, *Potamgeton pectinatus* and *Halophila ovata*, which are uprooted by wave-action and become bound together into plaques by the alga, *Lyngbya aestuarii* In the vicinity of Calcutta, the association with *Oscillataria germinate*, *Lyngbya confervoides*, and *Oedogonium spp* was very marked Covell and Singh (*loc cit*) found *sundaicus* larvæ in the Chilka area in association with thirteen types of plants and eight types of algæ, *Najas*, *Ceratophyllum* and *Hydrilla* among the plants and *Lyngbya*, *Anabena* and *Spirogyra* among algæ being the most important In fresh waters too, association with the same three plants and *Spirogyra* was observed (Venkat Rao and Ramakrishna, 1947)

Iyengar (*loc cit*) has stated that besides salinity, organic pollution of the breeding place is a cardinal condition of *sundaicus* breeding This is in accordance with the observation of Rodenwaldt and Essed (1925) in the East Indies that this species breeds readily in waters polluted with sewage Covell and Singh (*loc cit*) have recorded that the principal factor affecting the breeding of *sundaicus* is undoubtedly the presence or absence of putrefying masses of algæ and other weeds and that salinity probably operates only in so far as it affects the growth of the weeds All this suggests that water polluted by rotting organic matter favours the breeding On the other hand, Venkat Rao and Ramakrishna (*loc cit*) have shown that in fresh waters, the breeding occurs when the plants are still growing and when, therefore, no putrefaction occurs

In fact, when the plants are removed in the course of malaria control measures, the water becomes turbid and polluted and the green alga, *Microcystis auriginosa* grows in quantities and the breeding of *sundaicus* disappears

ADULT HABITS

Resting places—Christophers (1933) says that adults of *sundaicus* are found abundantly in houses and cowsheds Covell and Singh (*loc cit*) collected altogether 16,398 specimens, of which 8 835 came from huts occupied only by human beings, 4,237 from mixed habitations and 3,866 from cowsheds Thus, *sundaicus* is shown to rest in both human and animal habitations but predominantly in the former

However, Senior White (quoted by Covell and Singh, *loc cit*) observed that, in the same area, the numbers found in houses and cowsheds during cool weather are about equal but that, when it becomes warmer, the species does not appear to prefer cowsheds to the same extent

It must, however, be remembered that the density of *sundaicus* population varies to a very great extent from year to year Even in the Chilka area, where it has been in existence for about fifty years, its prevalence in any particular year is uncertain Fry (1911) and Sarathy (1932) investigated the area and encountered hyperendemic conditions without *sundaicus* having been located The latter author suspected its presence there and specially looked for it but could not find a single specimen During the first year of the investigation by Covell and Singh (*loc cit*), they were able to collect only 150 specimens for dissection, against 4,718 in the second year and 3,158 in the third year During the early part of 1942, Venkat Rao *et al* (1942) found the exceedingly heavy density of over a hundred per man-hour in houses The resting habits of *sundaicus* are, therefore, inapplicable for generalisation When the species is present in small or moderate numbers, it is likely to rest in houses or cowsheds according to its natural preference But, when it prevails in very large numbers as it does in certain years it has to overflow into other man-made structures or resort to outdoor shelters In such cases, the preferred resting places are difficult to ascertain.

Feeding time—The writer s experience indicates that, in normal years, feeding takes place more during the first half of the night

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Feeding time —The writer s experience indicates that, in normal years, feeding takes place more during the first half of the night

than in the second[3] When the species prevails in very large numbers, feeding may take place throughout the night and, those specimens which cannot get the opportunity to feed during the night, may feed in the early morning hours on persons seated in the darker parts of rooms

Food preferences —Covell and Singh (*loc cit*) have stated that 77 per cent of their total collection of 16,938 specimens was from rooms in which human beings spent the nights and that this fact was suggestive, indicating that *sundaicus* has a strong predilection for human blood[4]

Senior White (1947) obtained results of precipitin tests on 90 specimens, all from houses, which revealed the anthropophilic index of only 5 6 per cent Majority of these specimens were collected from a village at a time when the infection rates were high and were more conformable to endemic than to epidemic conditions If this small number is taken to be a representative sample, it only illustrates how a quite appreciable infection rate can exist in the face of a very low anthropophilic index

Gonotrophic cycle —There is no record of observations on this point

Swarming and mating —Two observations on the swarming and mating behaviour of this species were made in the Chilka areas by Venkat Rao *et al* (*loc cit*) both in January 1942 between 5 and 6 p m (Indian Standard Time) On the first occasion, there was a very large mixed swarm of both *A sundaicus* and *A subpictus* The swarm, consisting of an estimated number of at least 5 000, took place at a height of 6 feet over the elevated railway station platform The mosquitoes made dancing movements, both up and down and circular On the second occasion, instead of one large swarm at one place, there were several groups each consisting of only a few hundred specimens, scattered over half the length of the platform

3 Swellengrebel and S de Graaf (1919) have recorded that the species is voracious feeder and bites by day as well as by night —*Editor*

4 [illegible] to feed on man in [illegible] with human blood [illegible] present in normal [illegible] anthropophilic index

On both the occasions mating was observed A number of copulating pairs were seen and, in almost every case, such pairs came out of the group and were separated outside the swarm after a transient period Two copulating pairs were collected into a sucking tube; one was *sundaicus* and the other *subpictus* All mosquitoes collected from the swarms were fresh unrubbed and fed specimens.

The main breeding place of *sundaicus* at the time was the Chilka Lake about two miles away from the railway station As there was no evidence of swarming at any point between the railway station and the Chilka Lake, it appeared that the tendency of these mosquitoes to swarm at that particular spot was due to the radiation of heat from the raised stone platform and from the nearby range of low hills That *A annularis* does not require such conditions for swarming has been shown by a subsequent observation, swarming having been seen not on raised ground, but at lower elevations not far away from the lake itself (Venkat Rao, 1954)

Flight range—*A sundaicus* is a powerful flier [5] capable of traversing about two miles in search of food (Venkat Rao *et al*, *loc cit*) However, in exceptional circumstances when the density of the species is pushed up enormously, the dispersal may become much wider Covell and Singh (*loc cit*) collected adult specimens in villages up to about six miles from the lake shore, including one recently hatched specimen The range of infiltration stopped short of three miles where there was a belt of thick forest acting as a barrier There was no local breeding to account for the adults found in these villages

Hibernation—There is no information on this point [6]

Longevity—No direct evidence on this point is available Here again, longevity depends largely on the population density and, where the density varies very greatly from year to year, the longevity must also be affected and can at best be expressed in

5 Flight range of over one mile has been recorded by Covell (1924) and Porter (1924) Van Breemen (1919) believed that the species could fly as far as 5 Km—*Editor*

6. But the species being confined to the coastal areas with moderately warm climate all the year round there is no likelihood of the phenomenon occuring in its life cycle —*Editor*

terms of strong and lean' years. In Indo-China Treillard (1934) observed under laboratory conditions the species lived longer than either *minimus* or *candidiensis*

RELATION TO MALARIA

In the Calcutta area Iyengar (*loc cit*) found infection rates between two and six per cent Senior White and Adhikari (*loc cit*) dissected 659 specimens in the Chilka area and found a total infection rate of 2 3 per cent and a sporozoite rate of 0 7 per cent Covell and Singh (*loc cit*) dissected 9 307 specimens and found a total infection rate of 0 9 per cent and a sporozoite rate of 0 5 per cent Working with purely fresh water specimens Panigrahi (*loc cit*) dissected in Puri Town 617 specimens and found a total infection rate of 1 9 per cent and a sporozoite rate of 1 1 per cent In the fresh water areas of North Vizagapatam District Senior White *et al* (*loc cit*) dissected altogether 1,280 specimens and found a total infection rate of 4 7 per cent and a sporozoite rate of 2 6 per cent [7]

As the infection rates in the Chilka area and the adjoining North Vizagapatam area showed significant differences, the hypothesis was held out that in these areas the salt water form was practically harmless and the fresh water form was a potent vector In order to test the validity of this hypothesis the fresh water breeding in one particular locality of the Chilka area was completely eliminated without affecting the salt water breeding Then 495 specimens all obviously saline water breeders, were dissected and only one gut infection was encountered giving a total infection rate of 0 2 per cent and a sporozoite rate of *nil* (Senior White *et al*, *loc cit*)

It thus appears that whatever the status of *sundaicus* in West Bengal may be, the saline water form in Chilka area and further south is a poor vector and the fresh water form there is much more dangerous

There is another disturbing possibility where *sundaicus* is concerned Unlike many other anopheline species *sundaicus* is capable of invading and colonising new territories A fresh invasion

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7 Tyssul Jones (1950) has put forward indirect evidence to show that it is a vector in Kyankpyu Ramree Islands Burma —*Editor*

results invariably in violent epidemic outbreaks and, if the species can establish itself in the new area on a more permanent basis, *endemic conditions will soon prevail In fact, many areas in India* where *sundaicus* is now prevalent have been invaded in this manner in comparatively recent times

VARIETIES OR RACES IN *SUNDAICUS*

On account of the apparent differences in the behaviour and vectorial capacity of *sundaicus* in Orissa and North Vizagapatam areas, it was thought that the species might really be a complex of two races or forms, one breeding in saline and the other breeding in fresh waters Further work suggests that the two forms can be *distinguished by the difference in the number and shape of the* leaflets of their phallosomes (Venkat Rao and Ramakrishna 1950) somewhat similar to those in the corresponding forms of Sumatra found by Bonne Wepster and Swellengrebel (*loc cit*) Among the salt water forms, there appear to be at least two races or varieties in Singapore, according to Taylor (1943)

CONTROL

Anti-larval measure —To attempt to control the breeding of *sundaicus* through chemical larvicides like paris green on a large scale is a costly proposition Naturalistic measures described by Venkat Rao and Ramakrishna (1947) and Venkat Rao (1950) such as deweeding *etc* might be cheaper and more efficient However, while these measures are appropriate for limited localities, their extension to large areas would involve such an amount of expert organization and supervision which cannot always be afforded

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In Malaya, Nair (1949) used 5 per cent DDT kerosene oil solution as a barrier spray at the rate of one ounce of DDT per 1000 sq ft He found one round of application effective for 9 14 days Same formulations sprayed at the rate of 200 mg DDT per sq ft as indoor residual spray by Van Tiel and [illegible] *sundaicus* for a period of six months [illegible] erosene oil at the rate of one quart per [illegible] ported satisfactory results in the Chilka [illegible] nd Coastal area around Vizagapatam [illegible] asted for 6 8 weeks.

There is now evidence [illegible] res stance to DDT in two [illegible] Indonesia These localities [illegible] area of Tandjung Priok and [illegible] mately 200 k *lometers east* [illegible] the Djakarta coastal area to [illegible] as resistant to DDT as sun [illegible] out at Calcutta by the Mal [illegible] rat on of DDT for sundaic [illegible] anopheline species in India *Editor*

Anti-adult measures—It may be possible to control *sundaicus* by indoor residual spraying This method has actually been in force in the Chilka area for the last two years but the results are not yet available and, even if the method may prove to be successful, one has still to be careful when dealing with an elusive mosquito like *sundaicus* specially in view of the disquieting results observed by Crandell (1954) in the Djakarta area of Indonesia

In India *sundaicus* is capable of being eradicated owing primarily to the fact that it is occupying an extremely narrow marginal zone in the area of its distribution and is thus susceptible for eradication measures (Venkat Rao, 1955)

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V A *FLUVIATILIS* JAMES, 1902

By

M I D Sharma

(*Malaria Institute of India, Delhi*)

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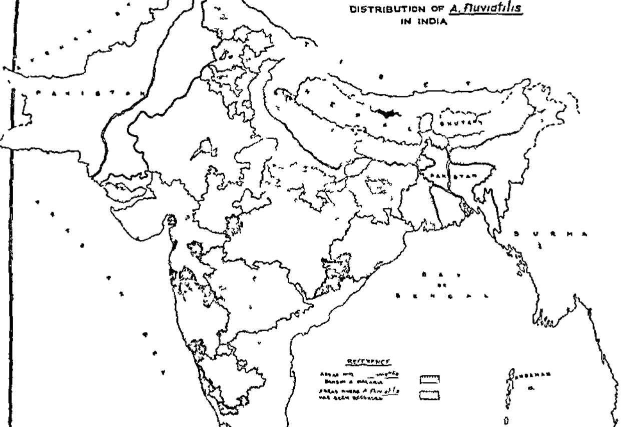
ANOPHELES FLUVIATILIS is a vector of considerable importance in India not only in hill and foothill regions but also in the vast irrigated tracts of the Deccan plateau It has been incriminated as a vector in parts of East Central India, Peninsular India and Western Uttar Pradesh Terai *A fluviatilis* is not commonly found below 1,000 ft or at altitudes over 5 000 ft above sea level

DISTRIBUTION

It has a very wide distribution in the Indian sub continent (Map 4) and has been recorded from Bengal, Assam, Orissa, Bihar, Uttar Pradesh, Punjab, Madhya Pradesh, Bombay, Madras, Hyderabad, Mysore, Vindhya Pradesh, Madhya Bharat, Rajasthan, Kutch Ajmer-Merwara Jammu and Kashmir and Delhi (*Covell* 1927, 1931a, 1931b, Puri, 1936, 1948) Outside India it is found in Ceylon Burma, Thailand Indo-China (Russel *et al*, 1943), Hongkong (Burke 1937), Turkistan, Iraq and Bahrein Islands, Persian Gulf (Covell, 1944)

BREEDING HABITS

Accordidg to Covell and Harbhagwan (1939) *A fluviatilis* is clear water breeder, normally found in irrigation channels and streams with grassy edges and a moderate current resorting to shallow wells during the monsoons when the usual breeding places are washed out by heavy rains They along with a number of other workers found that in the Western Ghats ricefields did not offer ideal breeding places for this species Vedamanikkam (1932) confirmed these observations and found that in the Wynaad (a hilly taluk of Malabar District in Madras State) breeding places like streams, ricefields drainage channels and contour drains with flowing water accounted for 88 9 per cent of the total number of larvæ of *A fluviatilis* collected, while the remaining 11 1 per cent were found in stagnant water collections in wells, ricefields, marshes and pools in the river bed Ramachandra Rao


DISTRIBUTION OF A. fluviatilis
IN INDIA
PAKISTAN
BHUTAN
PAKISTAN
BURMA
BAY OF BENGAL
REFERENCE
ANDAMAN

No 4

(1945), while confirming *the observations of previous workers* that streams and channels are the preferred habitats of the species determined that in Bombay State ricefields, both fallow and growing constitute important sources of the species

In the Wynaad, *A fluviatilis* was invariably found in the immediate vicinity of human habitations (Adisubramaniam and Vedamanikkam, 1943) while in the Hazaribagh Ranges and Jey pore Hills, breeding in significant numbers was found even up to at least half a mile from human dwellings (Venkat Rao and Philip 1947)

BIONOMICS OF ADULTS

Adult resting places —In North Kanara, human habitations were observed to be the common resting places of *A fluviatilis* (Jaswant Singh and Jacob 1944) Measham and Chowdhury (1934) in the Anaimallai Hills (Madras), collected only four specimens from cowsheds as compared to 199 from human dwellings In Bombay state also where this species is an efficient vector, the fraction of the population that elects to remain indoors during the day is found almost exclusively in human dwellings, with only five per cent of the indoor population occupying cattlesheds (Viswanathan, 1950) *A fluviatilis* is often found on lower portions of the walls, not more than five feet from the floor (Russell *et al*, 1946) Senior White (1941, 1946), Viswanathan and Ramachandra Rao (1943) Viswanathan *et al* (1944) and Issaris *et al* (1953) observed a significant fraction of of the population resting outdoors during the day time in Satpura Ranges and Singhbhum Hills North Kanara (Bombay) and Uttar Pradesh Tarai, respectively The outdoor resting places were found to be mainly on banks of streams where mosquitoes could find shelter under overhanging vegetation, projecting stones etc

Biting Time —*Viswanathan and Ramachandra* Rao *(loc cit)* in North Kanara (Bombay), found that females *A fluviatilis* entered a human shelter shortly after dusk and completed feeding before midnight in the main Viswanathan *e al* *(loc cit)* in the *same area observed that approximately 71 per cent of A fluviatilis* entered houses for feeding during the first quarter of the night, 19 per cent in the second, seven per cent in the third and three per cent in the last quarter In Mysore State, however,

Nursing *et al* (1934) found nearly as many *A fluviatilis* entering houses after midnight as before Senior White *et al*, (1945) in Jeypore Hills observed that the numbers entering between midnight and dawn were much greater than those entering before midnight and out of this 90 per cent of the females were either hungry or freshly fed Similarly, Jaswant Singh and Mohan (1951) in the Nilgiris observed *A fluviatilis* feeding in all four quarters of the night, most of the activity being confined to the second and third quarters indicating a difference in behaviour from the early feeding mosquitoes in Bombay State

GONOTROPHIC CYCLE

Senior White *et al* (1945) in their laboratory studies on *A fluviatilis* from Jeypore Hills, found that with temperature varying between 26 0° and 19 5° C mosquitoes with one feed only, took 48 to 96 hours for complete development of ovaries and 72 to 120 hours for oviposition Viswanathan *et al* (1944) in North Kanara (Bombay) found that this species had a 48 hour gonotrophic cycle from September to November and 72 hour cycle from December to February The findings of Jaswant Singh and Mohan (*loc cit*) in the Nilgiris on the other hand indicated that certain proportion of the females required only a single blood feed for the maturation of their ova a further proportion required a double feed in one night or on successive nights within one gonotrophic cycle thereby demonstrating the existence of the phenomenon of gonotrophic discordance'

ANTHROPOPHILISM AND ZOOPHILSM

Out of 1 681 specimens from the Wynaad, an antropohilic index of 97 per cent was obtained (Covell and Harbhagwan, (*loc cit*) Jaswant Singh and Jacob (*loc cit*) observed that 63 6 per cent of the *A fluviatilis* captured from North Kanara (Bombay) had fed on human blood Senior White (1947) found an anthropophilic index of 56 8 per cent in specimens caught from human dwellings in East Central India Barber and Rice (1938) in Poona (Bombay) and Ramsay *et al* (1936) in Assam found that specimens containing human blood were 4 6 and 3 8 per cent respectively *A fluviatilis* being primarily anthropophilic in some regions and zoophilic in others may be due to the fact that the species may be composed of two biological races which differ markedly as regards their preferential feeding tendencies The anthropophilic index of *A*

fluviatilis from the U P Tarai was 1 8[1] and 1 4[2] per cent in 1938 and 1939 respectively while it was found to be 47 per cent in 1949 52 (Ramakrishnan and Satya Prakash 1953) This marked change in the anthropophilic index in the course of about 10 years requires explanation In the past, the region was densely wooded with little human population and highly malarious in spite of the fact that the anthropophilic index of *A fluviatilis* was low The forests have now been cleared, large areas drained and reclaimed for extensive agricultural operations Greater opportunities exist now for a very much higher degree of mosquito man contact, than during the pre colonisation period (Ramakrishnan and Satya Prakash *loc cit*) With large scale indoor residual DDT spraying since 1947 in parts of U P Tarai it has been possible to colonise several thousands of people in the area (Srivastava, 1950) *A fluviatilis* in this area may be a mixture of anthropophilic and zoophilic races It is neither like the predominantly anthropophilic race of the Wynaad nor the predominantly zoophilic race it was originally considered to b* in 1938-39 (Issaris *et al*, *loc cit*)

FLIGHT RANGE

No records of observations on the flight range of freshly emerged *A fluviatilis* from natural larval habitats are available Adisubramaniam and Vedamanikkam (*loc cit*) in the Wynaad area, found larvæ of *A fluviatilis* up to not more than a thousand feet from human dwellings and conclud d that the species had a short range of flight in that area Whereas Venkat Rao and Philip (*loc cit*) in Hazaribagh Ranges found breeding of *A fluviatilis* up to at least half a mile from the feeding place and presumed this to be their usual flight range in search of food

SURVIVAL OR LONGEVITY

Regarding survival of *A fluviatilis* under field conditions there is no other record except that of Senior White *et al* (*loc cit*) who by release and recapture of marked mosquitoes in Jeypore Hills could follow up specimens for a period of 48 days Under controlled laboratory conditions Pal (1943) found temperatures from 20°to30°C and humidity from 50 to 80 per cent to be the optimum for the longevity of this species

1 Annual report of the Malaria Inst tute of India 1938
2 Annual report of the Malaria Institute of Ind a 1939

SWARMING

Mohan (1945) who studied the sexual behaviour of *A fluviatilis* in captivity noticed that swarming and mating could be induced by the use of artificial blue light inside the cage Subsequent studies showed that in warmer environment stimulus provided by blue light was not essential as swarming and mating took place in ordinary light and even in darkness (Mohan, 1951)

RELATION TO MALARIA

A fluviatilis is a very important vector in the foothill regions of Peninsular India comprising portions of Madhya Pradesh, Travancore Cochin, Mysore, Madras and Bombay states and in East Central India Mosquito dissection records so far available and the associated epidemiological data collected by various workers have been presented in Table I Till recently *A fluviatilis* in the north was considered of little importance as a vector The only published records of natural infection of *A fluviatilis* in North India appear to be those of Robertson (1910), at Saharanpur (Uttar Pradesh) who gave no details of his dissections, and Macdonald and Majid (1931) who reported two specimens with gut infection out of 23 dissected at Karnal Clyde (1931) dissected 460 specimens at Banbassa (Tarai region of Uttar Pradesh) with negative results In 1938 [1] a team from the Malaria Institute of India working at Bazpur in the same area found two gut infections in the 1817 specimens dissected Issaris *et al* (*loc cit*) however, in the same region found a gross sporozoite rate of 0 99 per cent during the years 1950-53 and incriminated *A fluviatilis* as an important vector of the area Available evidence would seem to indicate the possibility of the prevalence of more than one biological race of this species, judging from its different vectorial capacities in different parts of the country and the differences in its host pre dilection (Viswanathan, 1950) Brooke Worth and Sitaraman (1952) visualize two possible groups of *A fluviatilis* (1) anthropophilic, outdoor resting hill inhabiting, strongly vectorial and low in density and (2) zoophilic indoor resting, plains inhabiting, weakly vectorial and high in density

Usually hyperendemic conditions prevail in areas where, *A fluviatilis* is a vector Transmission with this species has been

1 Annual Report of the Malaria Institute of India for the year 1938

reported almost all through the year, the actual transmission period varies in extent in different regions Viswanathan (1946) has calculated that a density of 0 4 per man hour of *A fluviatilis* is the level at which it can carry on effective transmission of malaria

CONTROL

Larval control —Adisubramaniam and Vedamanikkam (*loc cit*) in the Wynaad recorded *maximum density of A fluviatilis larvæ* within 1000 feet of human habitations and found that antilarval measures like oiling of breeding places could be limited to places within 1000 to 1500 feet from human dwellings Venkat Rao and Philip (*loc cit*) however, in Hazaribagh Ranges ard Jeypors Hills found *A fluviatilis* breeding in significant numbers up to at least half a mile from the place of feeding and concluded that antilarval operations against the species could not safely be limited to less than half a mile from the area to be protected Subbaraman and Vedamanikkam (1943) in the Wynaad controlled the breeding of *A fluviatilis* by clean weeding the margins of breeding places In the same area Covell and Harbhagwan (*loc cit*) obtained encouraging results by herbage packing of the breeding places and recommended this as a cheap and effective method of malaria control

The extent of breeding places of *A fluviatilis* is so great and their antilarval treatment so difficult and costly that enforcement of antilarval measures for rural malaria control is almost impracticable For efficient malaria control reliance has to be placed on anti adult measures

Anti adult measures by pyrethrum spraying so successful against other species are not effective against *A fluviatilis* except when the costly method of daily spraying is adopted (Viswanathan *et al*, 1944, *Senior White et al*, 1945) *A fluviatilis spends* one day light period after feeding in the house and then leaves the house for some outdoor shelter to spend the remaining part of the gonotrophic cycle there irrespective of whether the cycle is completed in two, th ee or four days and is not always available when pyrethrum spraying is done (Venkat Rao, 1949) The only effective and economical anti-adult measure appears to be spraying of all houses with residual insecticides

Senior White (1945) and Senior White and Ghosh (1946) in Jeypore Hills found that DDT spraying at 50 mg per sq ft gave

effective protection against *fluviatilis* malaria and they recommended its two monthly application during the transmission season Viswanathan and Parikh (1946) and Viswanathan (1950) in Bombay, Ramakrishnan *et al* (1948) in South Kanara, Vedamanikkam (1949) in the Wynaad and Srivastava and Chakrabarti (1952) in Uttar Pradesh Tarai also controlled *fluviatilis* malaria effectively with DDT spraying at 50-56 mg DDT per sq ft repeated every 6 to 12 weeks In view of the encouraging results obtained in different areas so far, it can be stated with confidence that *fluviatilis* malaria in rural areas can be controlled effectively and economically by indoor spraying of houses with DDT and other residual insecticides

TABLE I

Area	Spleen rate per cent	Parasite rate per cent	Dissection of *A fluviatilis* Oocyst rate per cent	Sporozoite rate per cent	Total infection rate per cent	Observer
Jeypore Hills	—	—	—	1 8	1 8	Perry (1914)
Wynaad (Madras)	—	—	—	—	6 6	Horne (1914)
Mopad (Madras)	—	—	3 9	—	3 9	King and Iyer (19 9)
Anaimallai Hills (Madras)	—	—	6 4	3 9	8 8	Measham and Chowdhury (1934)
South Travancore	—	—	23 7	12 0	—	Mathew (1934
Wynaad (1938 39)	56 to 69	17 to 56	16 0	7 6	20 2	Covell and Har bhagwan (1939)
Nilgiris Distt (Madras) (1940 41)	46 5 to 84 5	33 3 to 45 6	9 7	10.1	17 3	Russell and Jacob (1942)
North Kanara (Bombay) (1942 43)	42 7	14 9	6 2	7 1	11 0	Jaswant Singh and Jacob (1944)
North Kanara (Bombay)	—	—	29 6	37 0	44 4	Viswanathan and Ramachandra Rao (1943)
Jeypore Hills (Orissa) (1944 46)	—	—	3 8	2 6	—	Senior White and Ghosh (1946)
Jeypore Hills and Hazaribagh Ranges (East Central India)	—	—	—	—	5 7	Senior White (1947)
South Kanara (Madras) (1947 48)	63 to 76	3 6 to 19 3	—	8 7	—	Ramakrishnan *et al* (1948)
Khandwa (M P)	—	—	—	1 28	—	Subramanian and Dixit (1943)
Bombay State Kanara Distt (1943)	—	—	—	—	7 0	Viswanathan (1950)
Nasik Distt (1947 49)	—	—	—	—	0 2	do
Panch Mahals Distt (1948 49)	—	—	—	0 8	0.8	do
Poona and Sholapur Distts (1948 49)	—	—	—	0.11	0 11	do
Kolaba Distt	—	—	0 44	—	0 44	do
Tarai Nainital Distt (U P)	—	—	—	0 09	—	Issaris *et al*, (1953)
Tarai Nainital Distt (U P) (1949)	—	—	—	11 1	—	Srivastava and Chakrabarti (1952)
Tarai Naini al Distt (U P) (1951)	—	—	—	1 6	—	do

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VI A MINIMUS THEOBALD, 1901

BY

A K KRISHNASWAMI
(*Malaria Institute of India Delhi*)

[June 21 1953]

AN important malaria carrier of the submontane regions of Eastern India is *A minimus* The type form of this species is the ch ef vector in the foothill regions and plains of northern Bengal and Assam and is respons ble for hyperendemic conditions often associated with black water fever and pernicious type of mal gnant tertian malaria (Covell 1949) Though recorded from various parts of central and peninsular India its vectorial status has not been establi hed in these parts *A minimus* is one of the few anophel nes of India which have been studied in great detul

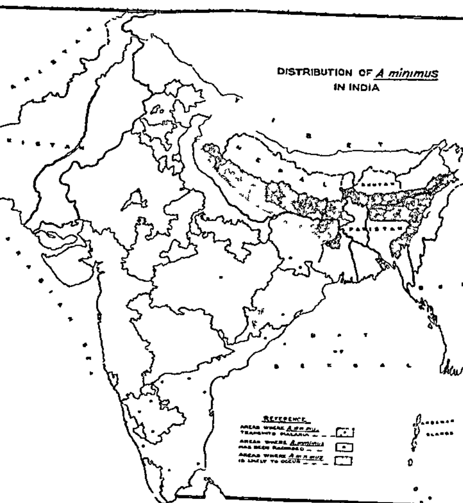
A minimus var *flavirostris* (Ludlow 1914) the principal vector in the Philippines (Russell 1933) has not been recorded in this country

DISTRIBUTION

A minimus has a wide distribution both in the north and peninsular parts of India (Map 5) The species has been recorded from Assam W Bengal B har Uttar Pradesh Chota Nagpur Konkan Hyderabad, Madras Mysore and Malabar

LARVAL HABITATS

Continuous breeding of *A minimus* has been observed only in clear unpolluted slow moving water with grassy edges (Covell 1944) Manson and Ramsay (1933) observed that clear running water with plenty of swamp vegetation and very little shade were best suited to breeding of *A minimus* They also found that fallow but not ploughed up fields were favourable to breeding of this species Thomson (1940) observed that stagnant places like marshes and ricefields were of no importance as breeding places In the latter however the presence of larvæ may be encount red due to drift from irrigation channels He further observed that larval prevalence in a breeding place was entirely due to selection of it by the gravid female *which prefers to deposit its eggs in* shady portions Tl e shade is usually provided by marginal vegetation More recently Thomson (1951) carried out crucial experiments both in the field and laboratory to determine the exact role played by the grassy edge He concluded that the grass apart from providing shade played an



No. 5

additional role in creating a zone of still water Full grown larvæ of *A minimus* were unable to resist a current of 0 20 to 0 31 ft per second (Thomson, 1940) Dark shady crab holes on the margins of streams without flowing water even in the absence of any vegetation, may form dangerous breeding places and can be overlooked In some foot hill areas *A minimus* was also found breeding in clean waters of shallow earth wells (Thomson, 1951)

BEHAVIOUR OF THE ADULT MOSQUITO

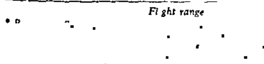
Daytime resting places —In North Bengal and Assam *A minimus* is a domestic species resting mainly in houses Manson and Ramsay (1932) found that 98 2 per cent of their collection of this species were from human habitations Thomson (1941) observed that this species rested mainly in the lower half of the walls often on the floor under cots A striking observation of Thomson (1941) was the patchy distribution of *A minimus* in houses some houses always yielding large numbers—due either to their location or their special suitability as resting places

A minimus has been reported to be a chiefly outdoor rester in China Chang 1939 quoted by Covell 1944) In India S nior White Ghosh and Rao (1945) collected *A minimus* from outdoor shelters among rocks near a stream in Jeypore Hill Tracts It could only be speculated at this stage whether this variation in resting habits of *A minimus* in different parts indicates the existence of more than one distinct biological variety

FEEDING TIME

Thomson (1941) observed complete absence of blood fed specimens among *A minimus* collected before 10 30 p m and concluded that most of the feeding took place after that time Krishnaswami (1952) confirmed these observations and found that the main feeding activity took place after midnight in the third and fourth quarters of the night

Flight range



that the nearest breeding place of *A minimus* was within two miles of the diurnal resting place and considered the flight range to be not less than one thousand yards. According to the experience of the workers in the Malaria Institute of India, Delhi the flight range of *A. minimus* in Assam and foot hills of West Bengal can be broadly taken as half a mile —*Editor*

By carefully designed marking experiments, Thomson (194.) recorded that females returned on the night of oviposition to the same house or group of houses for their next blood feed

Gonadotropic cycle —In the plains of Assam during hot damp season, *A minimus* was found to take two days to digest its blood meal as well as for the complete development of ovaries and oviposition (Thomson, 1941) In cold weather, however, this period was increased to 4-6 days

Senior White *et al* (*loc. cit*) observed in the Jeypore Hill Tracts that ovarian development took 72 96 hours, and that the completion of this cycle was more of an outdoor phenomenon

Feeding, digestion of blood and maturation of ovaries followed by oviposition continued right through the cold weather and no hibernation of females of *A minimus* was recorded in the plains of Assam (Rice and Mohan, 1936) This finding was confirmed by Thomson (*loc cit*)

Food preference —*A minimus of north and east India is mainly* a domestic species with a high preference for human blood Ramsay *et al* (1936) recorded the anthropophilic index as 85 7 per cent, while Senior White *et al* (*loc cit*) found the rate to be 92 4 per cent for the same species in the Jeypore Hill Tracts of Orissa Comparatively low anthropophilic indices ranging from 31 to 41 per cent were recorded for *A minimus* from Central Burma (Malaria Institute of *India unpublished records*) *Among the blood meals of A minimus* from Thailand, analysed at the Malaria Institute of India, 37 per cent were positive for human blood during the period October, 1949 to April, 1950 while the index for the period Aug —Sept 1949, was 71 2 per cent

Thermal death point —Exposure for a period of 5 to 10 minutes at temperatures ranging between 37° and 38°C was fatal to majority of females of *A minimus* (Thomson, 1940) Variation in humidity did not alter the mortality rate

Longevity —Senior White *et al* (*loc cit*) was able to follow up such specimens for a period of 19 days, by release and recapture of marked specimens Thomson (1941) observed that the survival rate was longer during the humid part of the year following the rains than during the hot dry pre monsoon period

EPIDEMIOLOGICAL FEATURES

Data collected by different workers on the various epidemiological aspects of *minimus* malaria during the last two decades have been presented in Table I

TABLE I

Observations on the epidemiological aspects of minimus *malaria*

Area	Spleen rate per cent	Parasite rate, per cent	Dissections of *A minimus*			Observer
			Oocyst rate	Sporozoite rate	Total infection rate	
Bengal	—	—	11 6	9 3	18 6	Iyengar (1940
Assam	8 2	35 8	—	1 8	—	Viswanathan (1941)
Jeypore Hills	—	—	—	4 4	—	Sen or White (1945)
Bengal	—	—	—	3 1	—	Puri and Krishnaswami (1947)
Assam	—	—	—	—	4 67	Manson and Ramsay (932)
Assam	57.0	45 0	—	—	—	Macdonald and Chowdury (93)
Assam	85 2	70 0	8 13	0 89	—	Gupta *et al* (1932)
Assam	55 0 to 73 0	59 0 to 68.0	—	—	6 2	Rice and Savage (1932)
Assam	—	44 4	1 4	2 .	—	Manson and Ramsay (1933)
Assam	—	—	4 4	1 3	5 56	Gupta *et al* 1933)
Assam	—	—	—	—	2 7	Lamprell (1936
Assam	90 86	69 13	0 67	0 67	1 35	Paul *et al* (1936)
Assam	68 0	49 0	8 3	1 4	8 3	Gilroy 1939)
Assam	—	—	2 0	3 0	5 0	Khan (1942)
Bengal Dooars	74 8	35 0	—	0 82	—	Ray (1948)
Thailand	—	—	0 93	2 47	3 14	Bhatia (1953)

Parasite and spleen rates —Hyperendemic conditions prevail in areas where *A minimus* is responsible for malaria transmission Spleen rates as high as 80-90 per cent and parasite rates of 50-70 per cent (Table I) have been recorded

Species plasmodia —Though *P falciparum* is the predominating species all the three common human plasmodia occur (Jaswant Singh *et al*, 1952)

Infection rates in A minimus —The highest infection rates among *A minimus* have been recorded by Iyengar (1940) a total with 20 gut and 16 gland infections among 172 specimens dissected giving rise to 18 6 per cent infection rate

Season—Transmission has been reported almost all the year round except during the months January to April Viswanathan (1941) obtained gland infections from June to December in Assam Macdonald and Chowdhury (1931) also in Assam recorded positive dissections from May to December while Iyengar (1940) working in Bengal found transmission during June to September only

Altitude—Khan (1942) recorded positive dissections of *A minimus* at a height of 1,200 ft above sea level on the Darjeeling hills

CONTROL

Larval control—The specialised nature of the breeding places selected by *A minimus* has been exploited by different workers in devising means for its control during its aquatic stages Manson and Ramsay (1932) stressed the value of silting as a direct anti larval measure against *A minimus* Diversion of silt laden streams into dangerous breeding places like 'Bhils or marshes was proved to be an ideal method of controlling breeding of *A minimus* (Strickland and Murphy 1932)

Shading especially of streams which are the sanctuaries of *A minimus* has been effectively utilised to control the breeding of this species Thomson (1940) studied the problem in detail and observed the total shading was necessary to ensure proper control He found that this method did not immediately put a stop to the breeding but on he contrary resulted in increased intensity of breeding When, however, marginal vegetation was removed an immediate reduction in the larval density was noticed Though oviposition was not hampered as shown by the continued presence of eggs and first stage larvæ it was concluded that shade *per se* played no part in the control of *A minimus,* but the absence of larvæ is mainly due to the secondary changes, chiefly the elimination of marginal vegetation which resulted in (a) increased velocity of flow at the edges (b) reduction of the available food for larvæ (Thomson 1951)

Anti adult measures—Viswanathan (1941) reported reduction in sporozoite rates to 0 5 per cent (comparison area 1 8 per cent) by weekly spraying of pyrethrum at one ounce per 1 400 c ft in the huts in tea estates of Assam By spraying twice a week the

infection rate among mosquitoes was reduced to zero (Viswanathan, 1942)

Based on the observation that this species mainly rests on the lower surface of the walls Weeks (personal communication) carried out field experiments in Burma to see if *A minimus* could be controlled by spraying the walls upto three feet from the ground only No appreciable reduction in mosquito population was noticed following the operation

Puri and Krishnaswami (1947) reported control of *minimus* malaria by residual spraying with DDT at 60 and 120 mg per s ft in the coolie huts of the tea gardens of Darjeeling Terai The *residual effect of such doses was found to last over 8-12 weeks*

Bertram (1950) recorded a high survival rate among *A minimus* from DDT sprayed houses and suggested that this species escaped from acquiring the lethal dose due to the excito-repellent action of the insecticide Macdonald (1950) discussing the observations of Gilroy in Assam reported 100 per cent mortality among *A minimus* trapped from treated houses Evidence supporting that *minimus* malaria was controlled in the Darjeeling Terai by indoor residual spraying with DDT was recorded by Krishnaswami (1952)

It can be stated that *A minimus* a vector of great importance is almost confined to rural areas in the foothill regions of India The control method of choice in such areas is the indoor residual spraying of DDT and the available evidence indicates that *minimus* malaria is amenable to control by this method

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VII A *VARUNA* IYENGAR 1924

BY

V VENKAT RAO

(August 17 1954)

A VARUNA, one of the members of what is commonly described as the '*fluviatilis* group *, was treated as a variety of *A minimus* or some times referred to as *A listoni* (*A fluviatilis*) before its isolation as a distinct species by Iyengar (1924) The position, however, continued to be somewhat confused for a few years more till it was clarified by Christophers and Puri (1931) Records of *A minimus*, and sometimes of *A fluviatilis*, pertaining to the period prior to about 1930 are, therefore, likely to refer to *A vaurna* in certain areas

Contrary to earlier observations, *A varuna* is now known to be a vector of only local importance in some areas, particularly in the hill tracts of East Central India Elsewhere, it may be a vector of minor importance as in Bengal (Iyengar, 1942) or a perfectly harmless Anopheles as in the Vizagapatam area (Senior White and Venkat Rao, 1943) However, in the areas of its importance, it is seen to be a powerful vector with infection rates as high as four per cent or more but, even in such areas, it always exists in association with *A fluviatilis* and *A minimus*, except in the Hazaribagh and Eastern Satpura ranges where it exists with *A fluviatilis* alone There is practically no locality in the Indian region where *A varuna* holds the field as the sole vector

DISTRIBUTION

A varuna has been found in Assam Bengal Bihar, Bombay, Gujerat, Konkan, Madras, Malabar, Mysore, Orissa, Travancore and Uttar Pradesh It has also been found in the Madhya Pradesh (Senior White and Adhikari, 1940) Outside India, it has been recorded from Burma, specially hill tracts, S China and Ceylon (Map 6)

*The three species viz, *A fluviatilis* *A varuna* and *A minimus* constitute this group Some records refer to them as the '*funestus* group' owing to their close resemblance to *A funestus* an African species

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(August 17, 1954)

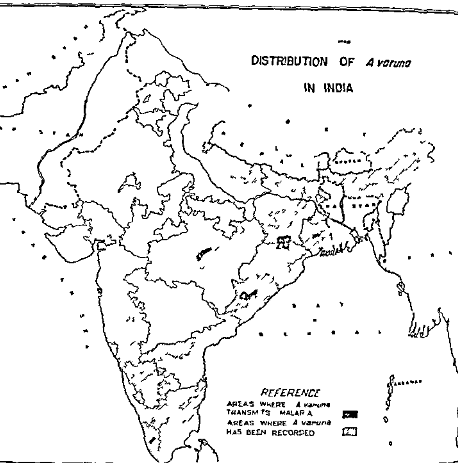
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Map 6

BREEDING PLACES

Iyengar (*loc cit*) found *A varuna* breeding in stagnant fresh water in ponds and ditches and, during and soon after the monsoon in collections of storm water around Calcutta Roy (1938) found *A varuna* breeding in stagnant water collections in association with algæ and other aquatic vegetation and with overhanging shade Puri (1931) found the larvæ in slow running streams and in wells in North Kanara District of Bombay. In Vizagapatam area, *kutcha* wells (without any masonry steining) were observed to be the most favoured habitats and accounted for about 60 per cent of the total collection of 6,502 *varuna* larvæ, the next best habitat being small slow running streams with plenty of overhanging

shade (Senior and Venkat Rao 1943) Russell and Rao (1940) observed that the irrigation as well as household wells were preferred breeding places of this species Senior White (1946) observed that seepage ricefields of the hill tracts in East Central India were very favourable for the breeding of *varuna* and of the other two species of this group On the Orissa Coastal Plain, Senior White *et al* (1943) observed breeding in some weed covered tanks but the intensity of breeding increased after the tanks were clean weeded Venkat Rao and Ramakrishna (1940) found larvæ on many occassions in somewhat dirty and foul-smelling stagnant waters at Bhadrak in Orisssa *A varuna* is thus seen to be capable of breeding in almost any type of water

Resting places —Adults of this species are according to Christophers (*loc cit*) frequently found in houses and cowsheds Senior White (1937) observed that in Jeypore Hills human habitations were preferred to a much greater extent than cowsheds for daytime resting The respective proportions of three species of the area in houses and cowsheds are as shown below —

ADULT HABITS

A culicfacies	1 0 to 30
A funestus	6 0 to 1 0
A jeyporiensis	1 0 to 6 5

From these observations, Senior White (*loc cit*) concluded that in that area '*funestus* is dominantly attracted to human habitations and only overflowed into cowsheds during the peak months Further observations covering a period of one year more in the same area fully confirmed this conclusion (Senior White 1938) He included three species *viz A fluviatilis A varuna* and *A minimus* under the *funestus* group which makes it difficult to calculate the actual number of *varuna* involved in his studies However he specifically stated that he combined the three species into one group because he found no significant differences in their breeding habits and infection rates and that for all practical purposes they might be considered together He dissected among others 1 877 *fluviatilis* 542 *varuna* and 396 *minimus* most of which were collected from human habitations If the three species in the adult collections referred to above are also in the same proportions there must be among them 230 *varuna* in houses and

36 in cowsheds which shows that over six times as many *varuna* are attracted to houses as to cowsheds

Comparing the house and cowshed collections of Singhbum Hills, Senior White and Das (1938) found that '*funestus*' was attracted almost exclusively to houses there, the proportion being 48 in houses to one in cowsheds Here too, their remarks are presumed to apply to *A varuna* also

The observations made by Senior White and Adhikari (1940) in the Eastern Satpuras constitute a landmark in the studies on *A varuna* as they indicate for the first time its potential outdoor resting tropisms They examined 108 breeding places and collected 136 *fluviatilis* and 503 *varuna* larvæ but the corresponding adult catch of both the species was only 36 While *varuna* was three times as common as *fluviatilis* in the breeding places it was more than three times less plentiful in houses and therefore they made the cautious but pointed remark that there was much more breeding of both the species than house catches indicated

Around Vizagapatam there is prolific breeding of *varuna* but the adults were exceedingly rare in houses and cowsheds Vigorous searches made in outdoor shelter such as the sides of running streams and *kutcha* wells and in thick scrub jungle in the vicinity of the breeding places were invariably negative, which led to special methods being devised A casual observation revealed that, if *varuna* was very rare in houses and ordinary cowsheds it could be collected in numbers in those cowsheds which exist in fields away from houses and which are constructed entirely of palmyra thatch with the roof brought down save at the entrance to about a foot of the ground level Such cowsheds are by no means rare in this particular area and may be seen dotted all over the country side In order to carry out a comprehensive study of *varuna* which, on purely epidemiological grounds was suggested to be a non vector by the present author, two contiguous huts of the above type were constructed, the only modification effected being that the roof was brought down to the ground level and embedded in an earth ridge with a view to prevent the movement of mosquitoes from one shed to another during the night except through the open front door One hut was human baited and the other buffalo baited Catches were made to 'emptying' daily for 12½

months in the former hut and for 16 months in the latter By this means, over 11,000 *varuna* were captured, 762 from the human-baited hut and 10 567 from the other (Senior White and Venkat Rao, 1943) It was thus shown that, in this area, *A varuna* had special and somewhat peculiar resting habits which involve, not houses or ordinary cowsheds or even outdoor shelters, but a special type of cowsheds situated away from houses

Pursuing his studies in the Eastern Satpura, Senior White (1941) produced presumptive evidence that *A fluviatilis* must be resting outdoors to an appreciable extent in that area As, during the study period, *A varuna* became extremely rare its outdoor resting habits could not be elucidated at the same time Some evidence of the exophily of *fluviatilis* soon became available from another quarter Working in the Bombay State with stained mosquitoes, Viswanathan *et al* (1944) observed that 60 per cent of *fluviatilis* in the warm weather and 40 per cent in cool weather left their breeding places in human habitations for outdoor shelters The position was further clarified by Senior White *et al* (1945) through their work in Singhbhum Hills During the four months of their study beginning in September they collected 90 *varuna* in unsprayed houses, 66 in sprayed houses and no less than 2188 from outdoor shelters, which, in this area were the steep side of small running streams, not far away from the villages The corresponding *fluviatilis* collections were 3 649, 151 and 91 respectively which clearly brings out the divergence in the adult bionomics of these closely related species Thus, though *varuna* represents no more than 2 5 per cent of the *fluviatilis* group population in unsprayed houses, it forms 96 per cent of the outdoor resting population of the same group Studying the wing and abdominable stages of the anopheline population in Jeypore Hills the same authors came to the conclusion that the *fluviatilis* group (including *varuna*) leave the house for outdoor shelters when the gonotrophic cycle is but half completed unlike *culicifacies* which rests at the feeding place till the digestion is almost complete Evidently, there is much outdoor resting by *varuna* in this area too

The above account shows that the resting habits of *A varuna* vary a great deal in different areas or even within the same area itself

Feeding time —The only record of feeding time of *A varuna* available to the author is that of Senior White *et al* (1945), in which they stated that numbers of the *fluviatilis* group (including *varuna*) entering houses between midnight and 5 a m are much greater than those entering before midnight The majority of this group in these collections were however *A fluviatilis* only small numbers of *varuna* and *minimus* being encountered but appears to be no ground to assume that the behaviour of *varuna* is different in this respect from *fluviatilis*, at least in the Jeypore Hills

Food preferences —It might be easy in the case of several anophelines to show that they are mainly or predominantly either anthropophilous or zoophilous The results of precipition tests for some common species obtained by Senior White (1947) which are shown in Table I illustrate the point

TABLE I

Result of precipitin tests of some anophelines

Species	Houses			Cowsheds			Out of Doors		
	No +	M+	A I	No +	A I	M+	No +	M+	A I
A culicifacies	564	62	11 0	1404	194	13 8	62	5	8 1
A annularis	430	13	3 0	1013	9	0 9	—	—	—
A pallidus	88	1	1 1	326	3	1 1	—	—	—
A aconitus	14	4	28 6	145	21	14 5	22	3	13 7
A jeyporiensis	26	6	23 1	314	27	8 6	37	1	2 7

No + = number positive M+ = Number positive for man
A I = anthropophilous index

The anthropophilous indices in the above cases are within certain limits similar, showing that the anophelines concerned are zoophilous either mainly or predominantly, whatever their resting places may be In the case of *fluviatilis* or *minimus* from East Central India it could be stated that with a of few exceptions which will be explained later they show marked evidence of anthropophilism *A varuna* however shows somewhat complex preferences There is no doubt that generally in the hill tracts of East

Central India *varuna* rates high as a vector or rather as a co-vector, along with A *fluviatilis* and A *minimus* and should thus be equally anthropophilic But even in these areas, there are certain variations (Table II)

TABLE II

Results of precipitin tests of fluviatilis *group from various localities in East Central India*

Species	Locality	Houses			Cowsheds			Out of doors		
		No +	M +	A I	No +	M +	A I	No +	M +	A I
A fluviatilis	Jeypore Hills	357	295	82 6	14	9	64 3	27	25	92 6
	Singhbhum Hills	321	222	69 2	362	33	9 1	12	4	33 3
A minimus	Jeypore Hills	124	112	90 3	9	6	67 7	5	5	100 0
	Singhbhum Hills	234	174	74 4	28	5	17 9	4	3	75 0
A varuna	Jeypore Hills	96	78	81 2	22	14	63 1	7	6	85 7
	Singhbhum Hills	124	66	53 2	114	7	6 1	347	14	1 0
	Vizagapatam	94	55	58 5	779	71	9 1	—	—	—

No + =number positive M + =number positive for man
A I =anthropophilous index

According to this table A *varuna* behaves similarly to A *fluviatilis* and A *minimus* in the Jeypore Hills and exhibits marked anthropophilism, irrespective of the source from which it is collected thus confirming that Senior White (1937 1938) was justified in combining the three species together into one group On the other hand in Singhbum Hills whereas *fluviatilis* and *minimus* collected from houses and outdoor shelters are anthropophilous and those from cowsheds appear to be mainly zoophilous, *varuna* collected from houses alone shows anthropophilism while *varuna* collected from cowsheds and outdoor shelters is markedly zoophilous the latter much more so than the former The situation in the Vizagapatam area is different altogether The anthropophilous index of

varuna from houses and cowsheds is similar to that of the Singhbhum Hills (there is no outdoor resting *varuna* in Vizagapatam) and *prima facie* conditions in the two areas appear to be identical It has therefore to be emphasised that at Vizagapatam *varuna* feeds on man only when it is forced to do so on the feeding journey and, in any case dissections show that but for a very few in the human baited hut infections are entirely absent either in house or cowshed collections This will however be discussed in more detail in a subsequent section The available evidence shows beyond doubt that, in this area *varuna* is a predominantly cattle loving species

There are thus significant variations in the food preferences of *A varuna* not only in different areas but also according to the resting places in the same area

Gonotrophic cycle — Senior White *et al* (1945) observed that, in the warm humid months of July and August *varuna* completes the gonotrophic cycle in 48 hours like *A minimus* in Assam (Muirhead Thomson, 1941) There are no records of observations in other months and also whether as in the case of *fluviatilis* and *minimus* there is any time lag between completion of ovarian development and oviposition However Senior White *et al* (1945) produced evidence showing that in *A varuna* too digestion and ovarian development do not always proceed simultaneously Table III shows the condition of the ovaries at the time of dissection which was made after the last blood meal was completely digested

TABLE III

Ovarian condition of A varuna *at the time of dissection*

Where collected	Number dissected	Ovaries per cent		
		(I)	(II)—(III)	(IV)—(V)
Sprayed houses	66	2	36	62
Unsprayed houses	90	1	31	68
Outdoor shelters	2188	8	48	44

About one third of the number are in early' ovarian stages, which indicates that repeated feeding may sometimes be necessary for *A varuna* to mature a single batch of eggs, denoting a condition described by Venkat Rao (1947) as gonotrophic discordance Careful inspection was always made of the damp cotton wool at the bottom of the Barraud box but no oviposition in transit was ever revealed and it cannot, therere, be stated as suggested by Jaswant Singh and Mohan (1951) that gonotrophic discordance is not to be presumed in such cases

Swarming —There is no record of swarming observations in respective *varuna* but such observations are essential, in view of the hypothesis put forward, of which mention will again be made later that far from being one species *varuna* stands for more than one distinct species or at least variety of biological race

Flight range —Venkat Rao and Philip (1947) observed the breeding of *varuna* up to about half a-mile from human habitations and presumed this to be its flight range

Hibernation —There is no information on this point as far as the author is aware

Longevity —No direct evidence regarding longevity of this mosquito is available However as *fluviatilis* and *minimus* are shown to survive a period of twelve days in fair numbers and as *varuna* shows equally high infection rates as the former the longevity of the latter should be much the same but this is at best presumptive evidence

RELATION TO MALARIA

In the Bengal area, infections were found in *varuna* by Iyengar (1942) in the Hooghly District and 24 Parganas and in the Howrah District by Roy (1939) It was therefore considered that *varuna* was an important vector, responsible for much of the endemicity in Bengal Subsequent detailed investigations made by Iyengar (1942) however revealed a different picture Malaria in deltaic Bengal was shown to be due to *A philippinesis* which was the main if not the only, vector with a total infection rate of 15 5 per cent and a sporozoite rate of 12 7 per cent whereas the total infection rate of *varuna* was only 0 7 per cent and the sporozoite rate nil Iyengar (1942)

therefore, concluded that, though *varuna* might be a potential vector and had been found infected in some places, it did not appear to play any important part in the deltaic area in determining malarial endemicity

As has already been stated *A varuna* exists on the Orissa Coastal Plain and around the Chilka Lake but is somewhat of a rarity there at least as an adult Senior white *et al* (1943) dissected 36 specimens in the former area but found no infections Senior White and Adhikari (1939) dissected three specimens from the Chilka Lake area with negative results Covell and Singh (1942) confirmed that *varuna* was encountered in this area only on a very few occassions and was not found infected at any time

Further south in the Vizagapatam area *A varuna* is present in very large numbers Senior White and Venkat Rao s (1943) dis sections from this area are shown in Table IV

TABLE IV

Dissections of A varuna *in the Vizagapatam area*

Where collected	Number dissected	G+	Gl+	I R	S R	
*Human habitations	762	—	2	0 26	0 26	*Ba ttrap huts
*Cowsheds	10 567	—	1	0 01	0 01	
Total	11 329	—	3	0 02	0 02	

G+ =gut infected Gl+ =gland infected
I R =total infection rate per cent S R =sporozoite per cent

It is evident that with such an exceedingly low infection index *varuna* cannot be classed as a vector of even secondary importance in this area

On ther hand there is indisputable evidence of the strong vectorial capacity of *A varuna* in the *Jeypore Hills*, as the dissections listed in Table V show

TABLE V

Dissection of A varuna *in Jeypore Hills*
(Senior White, 1937 1938)

Year	Number dissected	G+	GI+	I R	S R
1935/36	317	26	15	12 3	4 7
1936/37	189	8	2	5 3	1 1
Total	506	24	17	10 0	3 3

G+ = gut infected GI = gland infected
I R = Total infection rate per cent. S R = Sporozoite rate per cent

As already stated, Singhbum Hills present a somewhat different picture The infections encountered in that area are listed in Table VI

TABLE VI

Dissections of A varuna *in Singhbhum Hills*

Authors	Where collected	Number dissected	G+	GI+	I R	S R
Senior White and Das (1938)	*Houses*	*189*	*8*	*2*	*5 2*	*1 1*
Senior White and Appal Narayana (1940)	Human bait	153	8	3	7 2	2 1
Senior White *et al* (1945)	Outdoor shelters	2188	3	—	0 1	—

G+ = gut infected I R = Total infection rate per cent
GI+ = glands infected S R = Sporozoite rate per cent

The corresponding sporozoite rates for *fluviatilis* and *minimus* are —

	Fluviatilis	*Minimus*
Houses	1 8	3 9
Human baited	1 2	5 6
Outdoor shelters	—	15 4

Undoubtedly, *A varuna* resting in houses of this area is as dangerous as the other two species of the group, whereas that resting in outdoor shelters (and possibly cowsheds too) is practically harmless

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G+ = gut infected I R = Total infection rate per cent
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Houses	1 8	3 9
Human baited	1 2	5 6
Outdoor shelters	—	15 4

Undoubtedly *A varuna* resting in houses of this area is as dangerous as the other two species of the group whereas that resting in outdoor shelters (and possibly cowsheds too) is practically harmless

In the Hazaribagh Ranges which adjoins the Singhbum Hills *A minimus* is an extreme rarity *A varuna* is present in somewhat large numbers but is not as common as in the Jepore and Singhbhum Hills In the Hazaribagh Ranges altogether 131 *varuna* were dissected and three gut and two gland infections were found, the total infection and sporozoite rates being 3 8 and 1 5 per cent respectively During the same period 2 167 *fluviatilis* were dissected showing a total infection rate of 3 2 per cent and a sporozoite rate of 1 4 per cent in spite of finding high infection rates in *varuna* Senior White and Venkat Rao (1943) concluded that in this area the principal vectors was *fluviatilis* and that *varuna* was too rare to play any considerable part in transmission

A minimus is extremely rare in the Eastern Satpura Ranges also and *A fluviatilis* and A *varuna* dominate the field Senior White and Adhikari (1940) dissected 326 *varuna* and found a total infection rate of 7 7 per cent and a sporozoite rate of 3 7 per cent the corresponding rates for *fluviatilis* being 7 2 and 2 8 respectively The conclusion of these authors that *fluviatilis* and *varuna* are the principal vectors is thus justified In Travancore Mathew (1939) dissected 429 specimens with and oocyst rate of 2 3 and sporozoite rate of 1 6 per cent considered it a dangerous carrier

Outside India *varuna* is not shown to be a vector either in Burma or in Ceylon Fox (1950) says that in Burma *varuna* is unlikely to play any part in malaria transmission Adults of *varuna* are so rare in houses and cowsheds in Ceylon that, in spite of its prolific breeding it is not thouhgt to be a vector in that country (Rajendram and Jayewickreme 1951) The vectorial status of *varuna* is thus shown to vary widely from one area to another

POSSIBLE EXISTENCE OF VARIETIES OR BIOLOGICAL RACES

When they found that *A varuna* was a negligible factor in the epidemiology of malaria around Vizagapatam Senior White and Venkat Rao (1943) held out the hypothesis that the *varuna* of Vizagapatam might be specifically distinct from that of the Jeypore Hills And when a cattle loving form was discovered subequently in Singhbhum Hills along with a form of high vectorial potency Senior White *et al* (1945) observed that there were such extreme differences in the behaviour of this species as to furnish further evidence in favour of the hypothesis that *varuna* covers more than

one species or biological race The existence of biological races in certain species has been recognized for some time and it has also been suggested that, within a particular species complex, some races might be vectors and others not For instance, while *A culicifacies* is the sole vector of malaria in the Punjab and in some areas of South India, it is of no importance whatever in large parts of the country including East Central India, Assam, Bengal and Orissa No variations in the morphological characters of *culicifacies* from various areas have, however, been detected, which led to the conclusion by Russel and Ramachandra Rao (1942) that the ability of this species to transmit malaria depended mainly on its numbers On the other hand, Afridi *et al* (1939) produced evidence that the intensity of human feeding which must ultimately influence transmission, varied according to the relative proportion of man and animals particularly cattle The above observations were at variance with those made by Senior White and Venkat Rao (1943) at Vizagapatam where with adequate densities but with a higher anthropophilous index than in Delhi and South India, *culicifacies* did not play any part in transmission at all One is thus compelled, as it were, to revert to the question of biological races,for an explanation of these contradictions The references made by Huxley (1942) to the existence of biological races are given the force of axioms, he is so certain about them He goes on to observe that much of speciation is concerned with invisible phsiological characters rather than morphological differences, that groups may remain perfectly distinct though morpholog cally indistinguishable, that differences in ecological preferences may isolate groups as effectively as geographical or spatial barriers and that, certainly in most phyla and probably in all, there exist groups of individuals which are undoubtedly distinct in every sense except the accepted morphological one

When we find every conceivable difference in the ecology and behaviour of *varuna* in different areas or even within the same areas as indicated in the foregoing account, there is nothing improbable in the hypothesis that there are various species or races involved and it would be of interest, not only in an academic sense but also from the point of view of practical malaria control measures to carry out an intensive study of the phenomenon There is already some evidence which serves as a clear pointer in this direction The eggs of this species from the Jeypore Hills and Vizagapatam were

difinitely shorter (394 0μ) than the former (415 5μ) but, when then enquiry was extended to other areas of *varuna* prevalence, further differences appeared, which required *de novo* study of the whole matter, (Senior White and Venkat Rao 1943) Owing to preoccupation with other pressing work, these authors were unable to continue the study but it is hoped that other interested workers will do so hereafter

CONTROL

Specific control measures against *varuna* are not probably required in any area Along the east coast of India from Assam to Vizagapatam (and perhaps down to Madras or further south) this species is not of any practical importance In areas of its undoubted importance such as Jeypore and Singhbhum Hills and Eastern Satpura Ranges it is always associated with *fluviatilis* and *minimus* and, since the feeding and resting habits of atleast the house haunting adults of the three species are identical whatever measures are taken against these two species are *ipso facto* effective against *varuna* as well As these three species exist largely in rural areas and breed in the numerous seepages, streams and 'seepage rice fields', antilarval measures may be ruled out altogether there owing to their cost Senior White and Venkat Rao (1944) have shown that pyrethrum spraying against *varuna* and the other members of the group is not effective except when the costly method of daily spraying is applied On the other hand, DDT spraying has been shown to be an economical and effective method of controlling *varuna* (Senior White and Ghosh, 1946) They sprayed inside of houses with a five per cent DDT keorsine solution at the rate of one quart of the solution per 600 to 1,000 square feet (average dosage about 70 mg per square foot) and found it effective from two to six months, the residual effect being prolonged progressively with each successive spray round. Probably annual spraying at a dosage of 200 mg per sqare foot, using DDT water dispersible powder instead of solutions and emulsions, would be the method of choice, owing to its economy and efficiency

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BREEDING PLACES

Larvæ occur in clear slow-running water, in foot hill and other streams, in irrigation channels, along grassy edges of flowing water, seepages and other shallow water collections It is often found breeding in rice fields and occasionally in margins of swamps and tanks In South China larvæ have been taken from pools, ponds, swamps terraced rice fields (Chang 1940), and in seepage water and fallow rice fields (Chow, 1949) In Arakan, it was found breeding particularly in the parts thickly overgrown with vegetation often where standing water was not visible till a pool gathered around collectors feet (Macan 1950) Working in Tonkin Toumanoff (1932) mentioned breeding of this species in wooded hilly area with swampy valley, and mountainous regions with enough seepage water Jackson (1951) collected larvæ from water in the stubbles and observed that flooded fallow rice fields and fields with second crops ripening revealed larvæ of this species in hilly locales of Hongkong

The type form and its variety have similar larval habits (Boyd 1949) In Jeypore and Singhbum hills *A jeyporiensis* was found to prefer breeding in seepage fields over jungle nala and non-seepage fields (Seniorwhite 1946) The rice field breeding of the type form revealed that 75 per cent prefer fallow fields, 22 per cent broadcast and 3 per cent transplanted fields (Seniorwhite, *loc cit*) Like other members of the stream breeding group this species is found in water with temperature ranging from 23° to 33°C with an optimum at 28°C (Seniorwhite, *loc cit*)

BIONOMICS

Seasonal Prevalence —*A jeyporiensis* and its variety *candidiensis* abound in relatively dry period of the year Macan (1950) noted high density during April May in Arakan region of Burma where the rainfall occurs from June to October However, the same author (1948) found it in high numbers during the rains in Kabaw and Kale valleys of Burma Working in Hongkong, Jackson (1951) found little breeding during May to October (rainy season) and observed a high density during October and November In Jeypore Hills the type form is reported to be abundant during November to March while it disappears from August to September (rainy season) Singh and Jacob (1944) did not find the type form in

North Kanara (Bombay) during the monsoon They believe that this was due to continuous flushing of larvæ in the streams

Resting Places The type form is a proven indoor rester Various workers have observed that it prefers cattle-sheds and stables to human or mixed dwellings (Russel and Jacob, 1942, Singh and Jacob 1944 Seniorwhite *et al*, 1945) The ratio of daily cow-shed catches to daily house catches is 1378 1, (Seniorwhile *et al*, (1945) However the reports about variety *candidiensis* are conflicting As already mentioned, this may partly be due to the fact that the variety and the type form were not always recorded separately by workers outside India Macan (1950) and Watson (quoted by Macan, *loc cit*, and Postiglione and Venkat Rao 1956) found this form in considerable number near man at night These workers did not find them in houses during day and near cattle during night Feegrade (quoted by Postiglione and Venkat Rao, 1956) found good numbers in houses and cow-sheds in Bhamo area of Burma Macan (1948) collected 63 mosquitoes indoors of which only two to three per cent were with old blood He concluded that very few specimens spent the day in their feeding places The same worker in an experiment with human baited tents observed that all specimens tended to rest for an appreciable period near the source of food before making an attempt to feed Seniorwhite *et al* (1945) also observed that the type form moves away from the feeding s te for the second half of digestion being in the house for one daylight period only in each cycle

Seniorwhite and Ghosh (1946) noted the following preferential resting spots inside dwellings for the type form in Jeypore Hills —

(Figures in Per Cent)

Wall and door	*Thatch roof*	*Floor*	*Furniture*	*Clothing and hanging objects*	*Firewood*
42 5	34 0	5 5	12 0	4 5	1 5

According to Jackson (1951) variety candidiensis prefers dark corners and hanging clothes for resting indoors

Feeding Time —Macan (1950) observed that this species enters '*bashas*' between 22 00 hours and midnight most fed between 01 30 and 03 30 hours and disappeared In rooms without smoke, the

whole course of events took place earlier and some freshly fed mosquitoes were found between 21 00 and 21 30 hours There was no entry at dawn In night catches Nursing *et al*, (1934) collected more specimens (type form) between 4 hours to 6 hours than between 21 00 hours and midnight (54 0 and 46 0 per cent respectively)

Gonotrophic Cycle —Seniorwhite *et al* (1945) mention the gonotrophic cycle to be seventy-two hours for the type form However, it is likely that this may vary with seasonal temperature variations as is the case with other species

Anthropophilic Index —Seniorwhite *et al* (1945) mention that the type form has a high enthropophilic index in presence of human blood The variety *candidiensis*, also is regarded as having a high anthropophilic index Macan (1950) collected more mosquitoes using human baits than with cattle baits Jackson (1951) got the following results from precipitin test conducted on the variety in Hongkong —

Number examined	*Number positive*	*Antisera*					
		Man	*Cattle*	*Pig*	*Dog*	*Horse*	*Mixed*
214	188	103	72	2	1	8	2

However at one station (Woo Li Hop), where cattle and animals lived side by side their owners the precipitin test revealed equal numbers reacting to human and animal sera Toumanoff (1936) stated that in Indo China when caught in houses it always contained human blood and occasionally did so even when captured in stables or cattle sheds He classed it as highly anthropophilic with great animal deviation (as also proven by Jackson *loc cit*) Raynal and Gaschen (1935) found that seventy two per cent of 370 caught in dwellings in Indo China had fed on man

Flight Range —According to Jackson (1935) the flight range of *candidiensis* in Hongkong exceeds half a mile Seniorwhite *et al* (1945) experimentally showed that the type form in Jeypore Hills goes beyond 1,400 ft for ovipositing

Longevity —There is a very high percentage of survival for over twelve days in the cold wheather in the case of *A jeyporiensis* (Seniorwbite *et al*, 1945) No record of the longevity for varietal form is available

TABLE I

Incidence of **Plasmodium** *SPP, in Wild Caught* **A Jeyporiensis** *(type form) and var* **Candidiensis**

Locality	Reference	Number dissected G/G1	Numder positive G/G1	Per cent positive G/G1	Total infection	Per cent infection	Remarks
Burma							
Arakan-East Pakistan (Apr, 1944)	Macan, 1950	-/126	-/2	/166	2	1 6	
Kabaw and Kale valleys (May, Sep, Oct, Dec (1944)	Macan 1948	-/164	-/x	/x	0	0 0	
China							
Amoy Is (Fukien) (July Aug, 1931)	Feng, 1932	30/27	1/x	3 *3/x	1	3 3*	With only young pigmented oocysts (Data from authors' table)
Kwangsi	Feng, 1936	56	2/x	3 *6/x	2	3 6*	(Covell, 1944)
Yunnan	Ling *et al* 1936	53	x/1	x/1 *9	1	1 9*	(Covell 1944)
Mongshih, Yunnan (July-Oct, 1939)	Robertson, 1941	108	4/5	*3 7/4 *6	6	5 55	Six heavy infections
Hongkong, 1933 34	Jackson 1951	28706	1085/616	*4 8/2 *1	1701	5 9*	
		277	-/-		*14	5 05	

(Continued)

1	2	3	4	5	6	7	8
India:							
Jeypore Hills (Mar-Nov, 1912)	Perry, 1914	61/402	x/x	x/x	0	0 0	
Bengal	Fry, 1914	20	x/x	x/x	0	0 0	
Cachar (Assam) (Apr,-Dec, 1927)	Strickland, 1929	125	x/x	x/x	0	0 0	
Cachar, 1927-1929	Ramsay, 1930	888	x/x	x/x	0	0 0	
Kulasekharam, Travancore (Feb 1932-Sept 1933)	Iyengar, 1934	3833	3/x	0 08*/x	3	0 08*	98 oocysts in three infections One had well differentiated sporozoites Oocysts appeared mostly of *P falciparum* and a few were *P malariæ*
Mysore (1932-1933)	Nursing *et al.* 1934	671/667	2/x	0 3/x	2	0 3	Total dissections 674
Assam (1933-1934)	Ramsay *et al* 1936	2000	1/x	0 05*/x	1	0 05*	
Jeypore Hills (1935-1936)	Seniorwhite, 1937	318	4/x	1 3/x	4	1 3	Specimens showing infection were collected from human dwellings
Singhbhum Hill (1935-1938)	Seniorwhite and Das 1938	81	x/x	x/x	0	0 0	

(Continued)

1	2	3	4	5	6	7	8
Kulasekaram, Perumpazhuthoor (Aug , 1937-Aug , 1938)	Mathew 1939	49 3559	x/x x/x	x/x x/x	0 0	0 0 0 0	
Chedleth, Wynaad (1938-1939)	Covel and Harbhagwan, 1939	2494	x/x	x/x	0	0 0	
Singhbhum Hills (1939-1940)	Seniorwhite and Narayana, 1940	89	x/x	x/x	0	0 0	
Nilgiris (1940-1941)	Russell and Jacob, 1942	377	x/x	x/x	0	0 0	
Ketti Oct 1941	-do-	1	x/x	x/x	0	0 0	
Hazaribagh ranges	Seniorwhite, 1943	348	x/x	x/x	0	3 0	
Jeypore Hills (Mar , 1942-Feb , 1943)	Seniorwhite *et al* 1945	135	4/x	3 0/x	4	0 0	
North Kanara (May 1942 May 1943)	Singh and Jacob, 1944	1875	x/x	x/x	0	0 0	
Udaipur, Madhya Pradesh Aug ,-Nov , 1942	Roy and Biswas, 1942	-/32	-/x	/x	0	0 0	31 caught in human dwellings.
Jeypore Hills (Nov , 1944-Apr , 1945)	Seniorwhite, 1945	248	1/x	0 4/x *	1	0 4 *	

(Continued)

1	2	3	4	5	6	7	8
Indo China							
Tonkin (Jan 1931-1932)	Toumanoff, 1932	133	3/x	2 25/x	3	2 25	Oocysts filled with sporozoites
Red River Delta (1931-1935)	Gaschen and Marneff 1936	3419	22/18	0 64*/0 52*	34	0 99	
do-	Raynal and Gaschen 1935	2878			27	0 94*	(Horsfall, 1955)
Annam	Toumanoff, 1936	424	3/x	0 7/x	3	0 7	(Covell 1944)
South Indo China	do-	58	x/1	x/1 72	1	1 72*	(Covell 1944)
Tonkin	-do-	826	4/2	0 48* 0 24*	6	0 7	(Covell, 1944)

* Calculated figures
G for Gut Gl for Gland

RELATION TO MALARIA

The results of dissections of *A. jeyporiensis* and its variety *candidiensis*; recorded so far, have been set in Table I. No infective mosquito has been found amongst wild-caught specimens from present day India Oocysts have been recorded in specimens from Jeypore Hills (Seniorwhite 1937 and 1945, Seniorwhite *et al*, 1945), in Assam (Ramsay *et al*, 1936), in Mysore (Nursing *et al*, 1934) and in Travancore (Iyengar, 1934*a*) Contrary to reference available in the literature about var. *candidiensis* being a vector, this evidence leads to the conclusion that this varietal complex is not involved in malaria transmission in this country. However from very early times (Stephens and Christophers, 1902, Perry, 1914), due to its presence in large numbers in areas of high malaria endemicity this species has been considered a potential vector in areas of its distribution in India The oocysts in case of Iyengar's dissections are reported to have contained mature sporozoites Therefore, it may be just dame luck that has prevented incrimination of this species (type as well as variety) as a vector Future dissections may yet reveal an infective specimen in India.

Outside India, the varietal form (although not always designated so) is considered a premonsoon vector of importance on Burma-East Pakistan border (Macan, 1950), Hongkong (Jackson 1935, 1951), and Indo-China (Toumanoff 1932 1936), and of secondary importance in South China (Chow 1949)

All these areas are hyperendemic, and *A minimus* is the important associate vector.

CONTROL

No specific data is available on the control of *A jeyporiensis* var *candidiensis* by the use of insecticides (Singh *et al* 1954, Pal and Sharma 1955) Seniorwhite and Ghosh (1946) recorded upto ten fold reduction in density of the type form by spraying one quart of five per cent solution of DDT per 1000 sq ft Jackson (1951) eliminated breeding of the varietal form by preventing flooding of rice fields Covell and Harbhagwan (1939) prevented breeding of the type form by packing of rice field drains

It seems that proper care of irrigation drains and rice field drainage and the use of residual insecticides would check malaria transmission by this species

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IX. ANOPHELES LEUCOSPHYRUS DONITZ, 1901

BY

B S KRISHNAMURTHY

(Malaria Institute of India, Delhi)

[August 16, 1954]

A LEUCOSPHYRUS is readily distinguished by the broad white band covering the tibio-tarsal joint of the hind leg and was described as *A elegans* by James (1903) from Karwar District, Bombay State This was later synonimised as *A leucosphyrus* Donitz 1901 by James and Stanton (1912) *A leucosphyrus* in its different forms has since been identified in the oriental region from India to Celebes and from Java to Formosa The species complex is considered to be a group consisting of forms (Reid 1949) known by the following nomenclature —

1 *A leucosphyrus leucosphyrus* Donitz, 1901
2 *A leucosphyrus* var *elegans* James, 1903
3 *A leucosphyrus* var *hackeri* Edwards, 1921
4 *A leucosphyrus* var *balabacensis* Baisas, 1936
5 *A leucosphyruss* var *riparis* King and Baisas 1936
6 *A leucosphyrus* var *pujutensis* Colless, 1948
7 *A. cristatus* King and Baisas, 1936

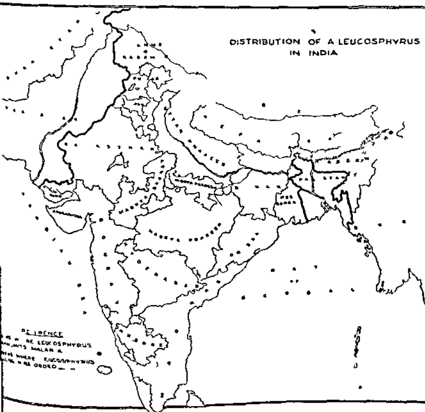
DISTRIBUTIONS

In India, it has been recorded from Assam, Andamans Bombay Bengal Coorg, Konkan, Malabar, Madras (South East), Mysore Travancore-Cochin (Map 8) Outside India, it occurs in Burma, Borneo, Ceylon, Celebes Indo China, Java, Malaya, Sumatra, Thailand, South China and Philipines

BREEDING HABITS

A leucosphyrus is essentially a jungle breeder Earliest record of its breeding habits are by Cogill (1903) who found that its preferential breeding places are jungle streams or pools co[illegible] dense shade and containing decaying leaves A [illegible] ings of subsequent workers reveals that this s

breeding in a great variety of waters Christophers (1912) in Andaman found them breeding in pools besides forest streams and Covell (1927) in pools in the open and disused wells In Bengal Terai, Puri (1931) found *A leucosphyrus* breeding in rain water in borrowpits along the side of the road, in thick forest Clarke and Choudhury (1941) in Assam reported breeding in pools made by elephant footprints in the open jungle Senior White (1926) in Ceylon found *leucosphyrus* breeding at the head of a ravine with no forest of any kind within some miles Macan (1948) recorded that one of the breeding habit was open sunlit McArthur (1947) reports *leucosphyrus* larvæ to be very shy They were easily disturbed and rapidly hid in the sediment at the bottom of either the pool or dipper as the case may be and remained submerged much longer than was the case with other species The larvæ were actually timed by him to remain submerged for five minutes or more He



Map 8.

emphasized that this feature of the larvæ remaining submerged for unusually long periods was found responsible for the deley in detection of *A leucosphyrus* as common breeder in Borneo McArthur (*loc cit*) and Reid (*loc cit*) recorded differences in the breeding habits of the varieties

BIONOMICS

Adult resting places —A leucosphyrus is widely believed to be a wild species inhabiting jungle under outdoor condition during day time In spite of that, it has frequently been captured in human habitations during nights Lalor (1912), Christophers (*loc cit*) Covell (*loc cit*) and McArthur (*loc cit*) have recorded indoor catches of *leucosphyrus* only during nights Roper (1914) in Borneo found them present abundantly inside defective mosquito nets in coolie huts engorged with fresh blood In Assam, Clarke and Choudhury (*loc cit*) caught them from the living rooms often inside the mosquito nets Clarke (as quoted by Macon, 1948) suggested that the fact that they were caught only from mosquito nets indicate that the nets acted as traps He considered that *A leucosphyrus* mosquito engorged with blood made less strenuous effort to find a hole in the mosquito net than she did when she was outside and hungry McArthur (*loc cit*) records that in Borneo these mosquitos rested for a short time on the walls of the houses where they fed and got away before dawn to their unknown outdoor resting places and were completely absent from the houses on examinations by conventional methods He also noted that this mosquito had never been found resting indoors either by day or night, unlike other mosquitoes it was rarely found feeding on animals but it was found only in human bait traps after long observations lasting for days Macan (*loc cit*) in a night catch of 128 fully fed *A leucosphyrus* females mosquitoes noted that only one mosquito had half digested blood and the rest were engorged with fresh blood This he correlated with the absence of *leucosphyrus* from the human dwellings during day and night catches and concluded that it did not rest indoors McArthur (*loc cit*) stipulated that probably they rest in the jungle where they return after feeding in the early hours of the morning Venhuis (1942) observed in East Java the adults of *leucosphyrus* resting on banks of streams Colless (1953b) has recently reported that 80 per cent of the females rested for ten to twenty minutes on the walls inside houses before feeding and almost all rested for thirty to sixty minutes after feeding

Feeding habits and biting time.—Roper (*loc. cit.*), Clarke and Choudhury (*loc. cit.*), McArthur (*loc. cit.*) and Macan (*loc. cit.*) all recorded as having caught *A. leucosphyrus* females engorged with fresh blood from defective mosquito nets. This signifies the preferential habits of this mosquito for feeding on man. Allman (quoted by McArthur, 1951) in N.W. Borneo caught eleven *leucosphyrus* in night by human bait and none by animal bait thereby indicating a decided preference for human blood. McArthur (*loc. cit.*) has shown that *A. leucosphyrus* adult female entered the house long after midnight fed on their sleeping victims and after a short rest fled quickly away to their undiscovered outdoor resting places before dawn. He also recorded that if this mosquito entered a human bait trap it did not wait long enough to get caught which explained its relative rarity in the traps. It was also observed by him to be present and feeding on sleeping persons in houses where the human bait trap was being operated unsuccessfully. Macan (*loc. cit.*) notes that the proportion of the *leucosphyrus* adults caught near man was disproportionately large to the number of larvæ found in the vicinity and this signifies that the adults from the nearby breeding places were attracted to man and thus converged to the human habitation. He fixed the time of biting activity of *leucosphyrus* as to start about 22.00 hours and to reach the maximum between 24.00 and 01.00 hours. Colless (1953b) also found peak feeding time to be at midnight. The proportion of mosquitoes caught before and after 01.00 hours being almost equal. But between 02.00 and 03.00 hours the mosquitoes suddenly departed from the dwellings and were very rare in catches after 03.00 hours.

Anthropophilic index.—Walch (1932) established by precipitin tests that 90 per cent out of 102 specimens of *A. leucosphyrus* tested had human blood in them and he also observed that this species readily fed on man. Ramsay *et al.*, (1936) in Assam and Northern Bengal found by precipitin tests that 75 per cent of 102 *A. leucosphyrus* were tested to have human blood. McArthur (*loc. cit.*) noted that this species had a much greater preference for human blood with an anthropophilic index of about 90 per cent.

Flight range.—Senior White (1926) reported that Bais in 1919 collected *A. leucosphyrus* from houses in Dutch East Indies 800 meters away from the nearest breeding place. McArthur (*loc. cit.*) and Colless (1953a) have taken the distance from the jungle margin to villagers where *A. leucosphyrus balabacensis*-borne malaria becomes

a negligible quantity as the effective flight range They have concluded the effective flight range of *A leucosphyrus* to be half a mile and range of diffusion to be more than a mile

RELATION TO MALARIA

Longvity and swarming — No information direct or indirect is available regarding the longvity and swarming habits of *A leucosphyrus*

A leucosphyrus is considered to be an important vector in Assam In Digboi area (Assam), Crawford in 1938 (as reported by Clarke and Choudhury, 1941) noted for the first time natural infection in *A leucosphyrus* This was later confirmed by Clarke and Choudhury (*loc cit*) Terrel (1943) incriminated this mosquito as a vector in the same area Outside India *A leucosphyrus* is considered to be a vector of considerable importance in Borneo McArthur (1950a) records *leucosphyrus* as the only anthropophilic species connected with hyperendemic malaria of the jungle ravines in Borneo The positive dissections recorded so far available are given in Table 1

CONTROL

The paucity of information about the bionomics, the rarity in routine catches and the reputation as a harmless mosquito has been *responsible in diverting the attention of various workers from* the control of *A leucosphyrus* It is now conclusively proved by McArthur (1951) that this species is not as innocuous as it was believed to be, wherever it is present and whenever dissected in adequate numbers it has been found to be infected and to be the carrier Its vectorial capacity has been very much underrated previously

Successful control of *A leucosphyrus* is reported by McArthur (1947) who employed naturalistic methods like jungle clearing and admission *of sunlight into the breeding places Earlier he failed* to control them by the usual larvicidal methods, and has since stressed the use of herbicides or weedicides

Gilroy (1951) in his field trials with suspensions of DDT and BHC in Assam against this species came to the conclusion that where the local conditions require six weekly replastering of walls 10 mgms BHC or 45 mgms DDT sq ft were equally successful in

TABLE I

Observer		Area	Number dissected	Number Gut	Positive Gland	Positive Gut +	Total	Percentage positive
Bais	(1919)	Saintar Estate, Sumatra	235	—	—	—	4	1·7
Doorenbos	(1931)	Kisiran, East Sumatra	504	—	—	—	5	1
Stoker	(1934)	Sarang Tioeng, Borneo	57	6	—	—	6	11 26
Goelarso	*(1934)*	*Kg Moeara Pangean, Dutch* Borneo	13	—	—	—	*1*	7 69
Toumanoff	(1936)	Indo-China	77	1	—	—	1	1 29
Clarke and Choudhury	(1941)	Digboi area, Assam	135	2	2	1	5	3 7
"		"	82	—	4		4	4 9
McArthur	(1941)	Tamburnam	639	7	13		20	2 97
Overbeek	(1941)	Colonization Boenta Celebes	1874	281			281	15 04
Macan	(1948)	Tamu Kabaw Valley, Burma	172	—	4		4	2 33
McArthur	(1949)	Labuan	727	9	16	5	30	4 26
"	(1950b)	Labuan	1109	6	8		15	1.35

controlling this mosquito Where a longer cycle of spraying is desirable 20 mgms gama BHC was preferable to any DDT dosage

In Sarawak (Borneo), WHO started control of *A leucosphyrus balabacensis* by residual insecticides in 1953 the results of which are not yet available Colless (1953*b*) tried a small experiment with residual insecticides but were not conclusive

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X. A CULICIFACIES, GILES, 1901

BY

M L BHATIA

AND

K S KRISHNAN

(*Malaria Institue of India, Delhi*)

[*October 29, 1956*]

INTRODUCTION

THE identity of this mosquito was established in the year 1901 by Giles who gave a brief description of specimens obtained from Hoshangabad, Central Provinces and the Berars Deccan (the present day Madhva Pradesh) He gave the name *culicifacies* to it because in the living state its resting posture resembles that of a culicine mosquitoe It was proved to be a vector of malaria by Cornwall in 1902 for the first time

SYNONYMY

(a) *A listoni* Giles 1901 corrected by Theobald (1903)

(b) *A indica* Theobald 1901 corrected by Theobald (1903)

(c) *A punjabensis* James 1911 corrected by Christop hers (1916)

RECOGNIZED VARIETY *A CULICIFACIES ADENESIS* CHRISTOPHERS 1924

Many workers have suspected from time to time that *A culicifacies* is composed of at least two forms, one having vectorial capacity while the other is inocuous Specimens of *culici facies* from areas in India where it is known to be a vector and from areas where it is not have been intensively studied for comparison (Russel and Rao 1942 Pal 1945) but no significant morphological difference has so far been detected in the egg, larvæ or adults The question of the possible existence of the sub species is still unsolved

DISTRIBUTION

The species is widely distributed in the Indian region East wards it extends through Assam Burma and Thailand to the Plateau of Yunnan in China Southwards it is predominant in Ceylon In the westerly direction it is distributed over Pakistan (West Punjab,

Sindh and Baluchistan), Afghanistan, Aden, Muscat (Arabia), Palestine, Iraq and North Persia Macan (1930) believed that specimen collected by Keys at Bushire in North Persia was wrongly designated *A sergenti* and was really *A culicifacies* It has been pointed out by one of the present authors that the original home of this species apparently lies somewhere in India with Delhi and Pattukottai as the axis (Bhatia, 1955)

BREEDING PLACES

The preferential breeding places of the species are fresh rainwater pools, irrigation channels, pools in river bed, borrowpits and cemented tanks in most localities. In South eastern Madras the types of breeding place which account for the bulk of *culicifacies* breeding are irrigation canals, wells and waste irrigation waters From these three types combined, Russell and Rao (1940 and 1941) obtained "nearly 70 per cent of all larvæ collected and about 58 per cent of all times taken" It is one of those species which is wellknown for its ability to breed in a great variety of breeding places In the Ennore Nellore coastal areas of Madras, shallow pits dug for watering young *Casuarina equestifola* plants have been described as virtual nurseries for the species (Russel and Jacob, 1939 *a*) The soil of this area is sandy and relatively infertile In Delhi area different types of breeding place of the species were classified by Covell (1939) as (a) excessive irrigation water, associated with canal system coupled with interference with natural drainage by embankments for railways, roads and canals (b) the annual rise of water level in the river Jamuna resulting in heading up of storm water drains, (c) large number of residual pools, aftermath of receding flood in the river, (d) vast number of excavations in the form of borrow-pits, pits in brick fields and quarries, (e) domestic breeding places in the form of water collections fed from hydrants and leaky sluice-valves, ornamental waters and unused swimming pools

In a reclamation area of Bombay State it has been found breeding in brackish water which contained up to 25 per cent of sea water (Chalam 1924) According to Young and Majid (1930) the soil in many parts of Sind (Pakistan) is impregnated with alkaline salts of magnesium, calcium and sodium known as "Kallar". Water standing on such soils, rich in these salts (Kallar) affords very suitable environment for *culicifacies* breeding These authors also observed

that the addition of leaves falling from *Babool trees (Acacia arabica)* on the water surface, along the edges of canal and their tributaries created highly favourable culture medium for the larvæ

In Punjab, the species has been found to breed in dirty cattle ponds, muddy borrowpits and roadside drains (Ramsay and Macdonald, 1936) These workers also noted that high sub-soil water table produces ideal swamps for *culicifacies* breeding Preferential breeding places reported by Davy (1912) are weedy pools under shade of trees and water in slow motion through tufts of grass The larvæ also flourish in irrigation channels with a considerable central velocity (2 4 miles per hour), provided the banks have bays and are grassy *Culicifacies* breeding in moving water was also observed by Mulligan and Baily (1936) in Quetta (Pakistan), where chief breeding situations were in connection with open irrigation channels arising from springs, wells, river and karezes The breeding was predominant in bays and backwaters along the edges of the channels Mulligan and Baily (*loc cit*,) however found that breeding was less prevalent in water under the shade of trees and in underground or partly underground water of karezes According to De Burca (1946) in Jubbulpore, (Vindhya and Satpura Ranges) it is essentially a stream breeder The larvæ are found in very large numbers in medium sized streams with sandy edges devoid of standing vegetation In smaller streams they particularly abound among *spirogyra* It has been noted by Barber and Rice, (1938) in Poona that breeding in wells is resorted to during the hot and dry weather when the favourable breeding grounds dry up In Pattukottai (Madras), the species breeds prolifically in wet fallow and young ricefields Russell and Rao (1942 *a*) have shown that *culicifacies* breeds abundantly in rice fields before and immediately after planting but when the plants attain a height of 12 inches it is no longer to be found there. The experiments of these workers have revealed that the height of dense shade over the breeding places by itself has no influence, either in attracting or repelling the ovipositing females Mechanical obstruction is the real determining factor Rao and Ramoo (1942) reported successful inhibition of *culicifacies* breeding along the margins of canals in Pattukottai (Madras) by cultivating *Vitex negundo* a parennial shrub on the canal banks The dense foliage of *Vitex negundo* creates both shade and mechanical obstruction The latter is probably a mere important factor than shade in preventing *culicifacies* breeding. In Kashmir, the species is to

in hill streams with pebbles in their beds (Jacob 1950) Still another type of breeding place is concrete cistern (Dow,1953) In Muscat the favourite breeding grounds are wells (Gill 1916) Aden (Hinterland) also presents a similar condition where var *adenensis* breeds in wells and pools in bed of streams (Christophers 1924) In the villages along the Arakan coast of Burma, *culicifacies* has been reported (Garewal 1937) breeding even in domestic water containers such as earthenware vessels and old tins But this finding has never been confirmed by any other worker Mehta (1934) in his experiments on A *culicifacies* with natural waters containing different amounts of free ammonia and solutions of ammonium carbonate concluded that oviposition took place indiscriminately in the laboratory in waters with up to 6 6 per million saline ammonia Observations of Russell and Rao (194 *b*) on the ecology of larvæ of *A culicifacies* in seepage filled borrow-pits in Pattukottai showed that no definite relationship existed between the fluctuations in the density of larvæ and any one of the following factors depth of water rainfall * microscopic vegetation hydrogen-ion concentration carbon dioxide dissolved oxygen, alkalinity hardness chlorine ammoniacal nitrogen nitrates, nitrites sulphates phosphates iron and poisonous metals The important factors which had significant bearing on the increase or decrease in the number of larvæ were

(1) Ageing of the pits The highest numbers of larvæ were found when the pit was newly dug There was a decline in the number as the pit grew older

(2) Plankton and amorphous matter Marked decrease in the number of larvæ was associated with increase in total plankton and amorphous matter Individual planktonic organisms however had no relation to *culicifacies* breeding but blue green algæ seemed to have detrimental effect

(3) Turbidity Water of the newly dug pits was turbid and of the old ones clear Certain amount of turbidity (40 per 100 000 may be favourable for the species)

In the turbid and mud coloured canal waters of South Eastern Madras the species has been reported to thrive (Russell and Rao, 1940)

* It is, however an important factor in creating fresh pools which are prolific breeding grounds of the species

Rain-water pools on clay and sandy soil are ideal for *culicifacies* breeding but on peaty soil it is not so (Russell and Jacob, 1939b)

Water temperature —Most species of anopheline larvæ may be found under field conditions in water whose day-time temperature near the surface is within a range of 24° to 35° C *culicifacies* larvæ however may be found thriving even at higher temperatures Russell and Jacob (1939c) reported that the species is found in water of casuarina pits exposed to sun having a surface temperature as high as 38° C Eggs and first stage larvæ are more resistant to high temperature, than fourth stage larvæ Thomson (1940) determined the thermal death point of the fourth stage larvæ of different anophelines He defined the thermal death point as the lowest temperature at which all larvæ were killed by an exposure of five minutes the temperature being raised slowly over a period of one and half to two hours He found that in *culicifacies* the thermal death point was as high as 44 0°C which was second only to that of *A vagus* whose thermal death point was 44 5-45°C Laboratory observations of Pal (1945a) show that *A culicifacies* larvæ can tolerate temperature upto 43 3°C The most favourable temperature according to him however ranged between 28°C and 32°C, the optimum being 32°C

ASSOCIATION OF SPECIES

Association of *A culicifacies* larvæ with those of other anophelines has been studied by Russell and Rao (1940) in South Eastern Madras Out of a total of 3014 positive larval collection made over a period of one and a half years the frequency with which the species was found by itself or in association with two other species was as follows

Combination of species			Time taken together
culicifacies	*culicifacies*	*culicifacies*	942
,,	*subpictus*	*vagus*	278
,,	,,	*pallidus*	217
,,	,,	*annularis*	120
,,	,,	*varuna*	107
,,	*pallidus*	*vagus*	72
,,	,,	*hyrcanus*	68
,,	*subpictus*	,,	62
,,	,,	*jamesi*	58
,,	*annularis*	,,	42
,,	,,	*pallidus*	41
,,	*jamesi*	*vagus*	31
,,	*varuna*	,,	26
,,	*hyrcanus*	,,	19

The number of times the species is found alone not associated with other species is significantly high (31 3 per cent times) Thus it is obvious that the species has its own preferred breeding grounds Furthermore, the most frequently associated species is *A subpictus*, which seems rather paradoxical at first sight but is in keeping with the fact that *A subpictus* is found in a great variety of water collections

OVIPOSITION

The process of egg lying in *A culicifacies* resembles that of *Anopheles maculipennis* group described by Bates (1940) Russell and Rao (1942) showed that *A culicifacies* in nature has the habit of ovipositing while flying and performing a hovering dance about two to four inches above the water surface During the dance they never touch the water surface either directly or indirectly by resting on the neighbouring bank edge or on any floating material They keep flying to and fro in relation to some fixed point The flight movements are vertical as well as horizontal as the female drops eggs Gravid females go to the breeding places at about 6 30 to 7 p m when it is dark enough to make them invisible to the unaided human eyes They lay eggs all through the night up to about 5 a m, the greatest number being laid during the first third of the night

The average number of eggs that a wild caught female has been found to lay during different seasons at Pattukottai according to Russell and Rao (1942) are as follows

Season (1940-41)	*Average number of eggs laid*
February-March	131
April May	111
June July	135
August-September	105
October-November	115
December January	123

This shows that there is no great difference in the fecundity of the females in relation to seasonal changes in that locality

SWARMING AND MATING

The most important factor controlling the swarming and mating of this species seems to be ample space for orientation In a space limited to 2 × 2 × feet size cages all attempts by different workers have failed to achieve fruitful results Russell and Rao (1942) successfully induced it to swarm and mate in an *aluminium wire screen cage with dimensions 40 × 20 × 10 feet* The cage was an outdoor one enclosing a small mud and thatch hut Essential requisites of the mosquitoes for feeds, resting and *oviposition closely simulating natural conditions were provided with*-in the cage Important points observed by these workers were as follows —Mosquitoes became active and left the diurnal shelter between 6 00 and 7 00 p m when a light meter at ground level facing the sky showed a reading of 5 0 foot candles When the light intensity came down to about 2 0 foot candles swarming started with a single male performing dancing movements Soon it was followed by a large number of individuals over a selected place to form a typical swarm The swarms were very compact measuring about one foot vertically and 1 5 feet above the ground The most remarkable feature of the swarms was the exact position within the wire netting cage where it always took place It was always on an east to west line about 23 feet long of clear space with out any obstruction and over dry earth The dancing individuals in a swarm always showed a forward and backward floating movement facing east Variable number of females could be found in the swarm but their number was always much smaller than those of males

Number of individuals taking part in a swarm varied from 4 or 5 to more than a hundred Position of male and female during copulation was end to end Thus connected they slowly flew away from the swarm in all directions and separated on coming in contact with vegetation or other objects Copulation was observed to last up to 15 seconds It was also noted that sometimes mating took place even without the formation of swarms but the time and place selected for the purpose was the same as that of the swarms It was also observed that the copulating females in most cases had taken a blood feed before mating No clear relationship of meteoro-*logical condition and swarming was noted except that immediately* before or after rain it did not occur

RESTING PLACES

A culicifacies is a predominately domestic species preferring human dwellings and cattlesheds for its daytime resting Reports regarding the relative prevalence in cattlesheds and houses are rather conflicting In Bengal (Timbers 1935) the number resting in houses was higher than that in cattlesheds Senior White (1937) on the contrary found that in Jeypore greater number were to be found in cattlesheds than in human dwellings Senior White *et al* (1945) reported that the ratio of cattlesheds to house catche was opposite of what they found in a locality near the Western Ghats Findings of Senior White and Das (1938) at Singhbhum hills and of Perry (1914) in Jeypore Hill tracts again go to show the preponderance of the species in cattlesheds In Delhi urban area Afridi Jaswant Singh and Harwant Singh (1939) also found that the number captured from cattlesheds was higher than that from human dwellings although both shelters were in the same courtyard That the species may feed in one place and rest in another is now well recognised Afridi *et al* (*loc cit*) have reported that human blood fed specimens of this species were at least twice as numerous in cattlesheds or combined human and cattlesheds as from purely human habitations Similarly Senior White (1947) found that human blood fed specimens could be found not only from human dwellings but also from cattlesheds and even outdoor shelters Larger percentage with human blood feeds were from cattlesheds There is thus greater evidence to show preference of *A culicifacies* for cattle sheds as daytime resting places Apart from the proximity of the source of blood feed other factors which determine the resting places are the cool, dark and humid atmosphere protected from draughts The climatic conditions most favoured by the species are a temperature range 77°-86°F in combination with relative humidity of 60-80 per cent (Pal 1943) Suitable ecological conditions may be encountered by the mosquito even in outdoor shelters Instances are available which show that the species does utilise outdoor resting places Perry (*loc cit*) found it resting in significant numbers amongst the roots of thick bushes in Jeypore hills Senior White (1946*a*) found variable number of blood fed specimens taking shelter during daytime in nala banks in Singhbhum nala banks and bushes in Jeypore hills caves and culverts in Hazaribagh and Korea Coalfield areas The species is also known to utilize outdoor resting places to some extent in Baluchistan where they have been found in considerable

number in karezes and caves quarter of a mile or more away from human habitations (Mulligan and Baily, 1936) Evidence of *A culicifacies* resting in outdoor locations has also been furnished by Rajendram *et al* (1950) in Ceylon They could catch it by means of human baited traps in dense jungle in which there was scrub as well as high forests as far away as 4-7 miles from human dwellings So far it has not been found under outdoor conditions in Delhi area and its environs in spite of repeated searches The species is clandestine in its resting habits It has been found hiding in holes and crevices, of the roof (James and Liston, 1911) Christophers (1933) has stated that it hides in holes among dungcakes and in chaff etc It has been observed to penetrate deep into thatch of cow-sheds and even into the bristles of nail brushes (Clemeshaw, 1934) Recently a peculiarity observed by us in Vindhya Pradesh was that this species was seldom found in sheds where goats alone were kept At Bushehr in Iran adult *A culicifacies* have been found to rest in large concrete cisterns inadequately screened in which rain water is stored (Dow 1953)

Aryaratnam (1955) in Ceylon found that the least utilized situations inside houses were hanging clothes and other objects which is contrary to the findings in Delhi (Pal and Sharma, 1952) One of the situations most preferred by the species in domestic resting places observed in Delhi and Vindhya Pradesh is the underside of horizontal surfaces such as roof and shelves along the walls Cobwebs along the corners and roofs are also the favoured resting places Rafi (1955) has reported from Punjab, (Pakistan) that *A culicifacies* was found uniformly distributed throughout the whole wall surface inside the room This is at variance with Aryaratnam s (*loc cit*) observations in Ceylon where this species was found to rest mostly below six feet

SEASONAL PREVALENCE

Fluctuations in the adult density of mosquitoes is interlinked with the larval habitats of the species For this reason the most important factor is the extent to which the favourable breeding places are available Afridi *et al* (1940) were of opinion that no definite relationship can be established between the meteorological condition and numerical variation in *A culicifacies* density But they believe that it is regulated by some unknown seasonal element Russel and Rao (1941) were also doubtful of temperature and humidity having

great consequence in the seasonal fluctuation in the density of this species in Pattukottai area The observations made by us in areas around Delhi during the past four years also show that meteorological conditions like temperature and humidity do not seem to have much significance on the numerical prevalence of this species The extent of irrigation and irrigation seasons showed positive correlations with *A culicifacies* density in Pattukottai Rainfall is another factor which has important bearing on the seasonal prevalence of the species over wide areas Heavy rainfall may flush away the favourite breeding places and result in reducing the adult population On the other hand if it is of moderate intermittent type it may create and maintain large number of suitable breeding places to build up high adult density This is well borne out by the observations of Brookeworth (1952) in Mysore State The unknown seasonal element referred to by Afrid *et al* (1940) may perhaps be explained in the light of Russel and Rao s (1942b) work who showed that freshly formed water collections devoid of amorphous matter were the most prolific breeding sites of this species Such collections are associated with rainfall and irrigation water

The seasonal prevalence of *A culicifacies* for undivided India as a whole was fully discussed by Afridi and Puri (1940) They divided the country into seven regions and have classified the seasonal prevalence according to the data published by workers in those different regions These regions and the seasonal prevalence of the species are briefly summarised below

(A) *North West Frontier Province and Quetta (Pakistan)*—The period of low prevalence is from January to May and peak density being in September-October After which it begins to decline and comes to a very low level in December

(B) *West and Central Punjab Derajat (N W F Province)*—In this region the months of low density are December January and February During the rest of the period there are two peaks of high density The first peak is during the spring months March April and the second one which is higher during September October

(C) *South East Punjab, Sindh, Western U P, South Bihar and Orissa Jeypore hill tracts Hyderabad State and parts of Madhya Pradesh*—Here the species occurs in significant numbers th

the year though periods of comparatively low densities are January-February and May June with two peaks one in March April and the other September

(D) *Eastern Terai Assam Bengal W Coorg Malabar (hill areas) and S W Coorg*—Here the species occurs throughout the year but with high prevalence during February to May

(E) *Eartern U P Riverain Tracts in U P and N Bihar*—In this region the months of low density are July August with two peaks first in April May and the second in October November

(F) *Madras inland tracts S E Coast E Coorg and low lying areas of Malabar*—The month of low density in this area are July September with peaks in December-January

(G) *Vizagapatam area and Madhya Pradesh*—*A culicifacies occurs throughout the year with prolonged period of high prevalence from July to December*

Russel and Rao (1941) have however shown that in Pattu kottai Tanjore Distt the period of greatest prevalence of the species was in August Septembr This observation is not in agree ment with type F of the maps published by Afridi and Puri (1940)

In addition to the above Viswanathan (1950) has given the seasonal prevalence of this species in some of the areas of Bombay State

In Bijapur Distt the highest density is in mid September and the numbers fall off rapidly from December In Nasik Distt the density of this species remains high from November to July In West and East Khandesh districts the highest prevalence is from August to October while in Poona and Sholapur Distts fair number of *A culicifacies* occur throughout the year but the peak is from June to November and there is rapid decline from October In Durg Distt the density of the species remains high all through the year highest being in July In Broach Distt, *A culicifacies* shows a sharp increase in density in August while the peak is reached in November Fair numbers are maintained till the end of March

In Ahmadnagar Distt *culicifacies* density remains high all through the year except in May

Jaswant Sing and Jacob (1944) in N Kanara found the largest number of this species in April and June and least in October

X *A culicifacies*, Giles 1901

DENSITY

A culicifacies being a predominantly zoophilic species has to have a high adult density to be able to transmit human malaria. The statment of Viswanathan (1950) that the vectorial capacity of this species "in any area is determined solely by its numerical prevalence" does not always hold good It has to be associated with the longevity factor Where this species is a vector its density is no doubt high but on the other hand instances are available where high density prevails in the absence of malaria transmission One such instance is provided by Viswanathan himself (*loc cit*) in his report that in Khandesh District (Bombay), the species continues to show fairly high density during the hot and dry months of February to April without malaria transmission A still more striking example of this was recently met with in Vindhya Pradesh during a survey in April 1954 Of the different areas examined, two that showed highest *culicifacies* densities of 131 per man hour at Nangayi and 134 per man hour at Marwas were among those which showed the lowest spleen rates—9 per cent in the former and 18 per cent in the latter This just goes to show that high density alone is no criterion of its ability to transmit malaria It is explainable by the meteorological conditions which effect the longevity of the species

The classical work of Russel and Rao (1942b) on the density of *A culicifacies* in relation to malaria endemicity has provided a very valuable index Comparing the *culicifacies* densities of two contiguous areas (in South India) meteorologically identical but one malarious and the other non-malarious they came to the conclusion that provided other factors were favourable 5 0 mosquitoes captured per man hour represented the minimum critical density of the species They claim that below this figure no transmission of the disease can take place

Some of the figures that are available on the per man hour density of *A culicifacies* during transmission season in different areas are presented below —

(1) In the year 1939 41, during which malaria in Delhi was practically negligible, the per man hour density of *A culicifacies* never exceeded 3 4 (Pal, 1945b) There was a severe outbreak of malaria epidemic in this State in autumn of 1942 showing a rise in per man hour density

to 11.6 in September, In the same month of the post epidemic year 1943 it was even higher, *viz* 25 0

(2) Viswanathan (*loc cit*) reports that this species in Bijapur District (Bombay) during the entire transmission season has a density at levels several times higher than 5 0 per man hour in mid September In Dharwar District it does not go much above 8 or 9 per man hour

(3) At Tuvaranguricbchi in Tanjore district (S India) during the transmission season July to November 1939, Russel and Knipe (1940) showed that the density of species varied between 7 5 and 28 4 per man hour highest being in August

(4) Average figure for density of the species in the entire Pattukottai taluk derived from 1937 to 1940 by Russell and Rao (1941) are

July	11 0	per man hour
August	25 7	,,
September	20 3	,
October	11 6	,
November	9 9	,,

The highest level reached was 40 per man hour in August of 1939 and 1940 (Russell and Roa 1942)

(5) *Viswanathan and Gadre (1950) reported that the density* in Ahmedabad District (Bombay) during September varied from 13 0 to 25 8 per man hour

In most of the areas cited above, the density of the species during non-transmission periods is known to remain icvariably below the critical level of 5 0 per man hour As such it may be regarded as a further proof in support of the conclusion derived by Russell and Rao (1942)

The index 5 0 per man hour may thus be adopted with advantage for determining the timely application or reapplication of control measure in areas of A *culicifacies* transmitted malaria

LONGEVITY

Atmospheric temperature and humidity play an important part in determining the longevity of a mosquito The longevity increases as temperature decreases and more especially as relative

humidity increases Mayne's (1930) studies on *A culicifacies* under laboratory conditions indicated that adults lived longer at low humidity provided the temperature was also relatively low. He found that for a relative humidity in the range of 80 to 88 per cent the favourable temperature was 80°F while at 57-62 per cent relative humidity it was 67°F The duration of adult life with these combinations were.—

Humidity (Per cent)	*Temperature*	*Longevity in days*
80 88	80°F	7 21
57-62	67°F	10-21

Reduced humidities at the same temperatures brought about a arked reduction in the longevity of *A culicifacies* as follows

umidity (Per cent)	*Temperature*	*Longevity in days*
40-46	80°F	1-4
51-52	67°F	3-4

Covell and Baily (1930) in Sind and Macdonald and Majid (1931) in Karnal concluded from the absence of sporozite infections that the longevity of the species was less than ten days during dry months Hicks and Majid (1937) also held the opinion that the duration of adult *A culicifacies* varied inversely as the saturation deficiency in the atmosphere Observations under laboratory conditions by Pal (1943) showed that at low temperature 55°F (12 9°C) high humidity (80 to 100 per cent) was advantageous for the promotion of longevity and adult females lived for four to eight weeks He also reported that at higher temperatures 25°C (77°) and 30°C (86°F) survival at a relative humidity of 60 per cent was considerably longer than at either higher or lower humidities At 25°C the longevity was 14 to 28 days and at 30°C it was 6 to 18 days Field studies on longevity of *A culicifacies* by Afridi *et al* (1940) by releasing a large number of gold dusted specimens near Karnal (Punjab) revealed that specimens released in November and December lived upto 56 days Those released in dry months particularly May and June were very short lived They also found that the longest period any adult remained alive in caged condition was 49 days in November and December and the longest average life of about 24 days was also in the same months Bose (1934) surmised that *A culicifacies* lived at least four months from July to November in the adult form because no larval breeding could be detected

during the period in a flooded area in Birnagar (Bengal) Siddons (1944) studying infection of *A culicifacies* with different species of human plasmodia came to the conclusion that a lower temperature within the range of 94 to 70° F particularly when combined with increased relative humidity increases the period of survival Russel and Rao's (1942e) finding on the longevity of *A culicifacies* under simulated natural environments in Pattukottai agree in general with figures obtained by Afridi *et al* (1940) from Northern India (Karnal) under field conditions Maximum longevity of the females in different months in the two areas compare as follows

Months	*Maximum longevity in Karnal*	*Maximum longevity in Pattukottai*
May	9	11
June	14	14
July	24	24
August	14	33
September	25	23
October	32	32
November	45	
December	56	

There were marked differences in the temperature and humidity of the two areas but their combinations were similar to the corresponding longevity figures which are more or less the same Russel and Rao s (1942) work also reveals that at Pattukottai the maximum longevity of the species varied from 8 to 11 days during May to early June From mid June to mid July it was 13 to 16 days In the later months up to end of November it always remained above 21 days Males are very short lived The maximum longevity noted for them is eight days The most important feature of Russell and Rao s (1942) studies was regarding the rate of mortality of adult females They found that death rate among them was 60 per cent every two days and reduction in population took place by geometric Nearly 97 per cent of *A culicifacies* die before the das the remaining three per cent of their

population have any chance of carrying on malaria transmission They calculated that the probable duration of life of the species was two days and the average life was only four days But in every batch there were invariably one or two specimens which were much longer lived than the rest As this species is known to transmit all three species of human plasmodia its density in any particular area must be very high to make its three per cent (longlived) population effective transmitter

BITING TIME

Clyde (1931) reported from his observation in U P Terai that the species bite human beings during day as well as night time King and Krishnan (1929) recorded similar observation in Nellore District (Madras) but subsequent workers elsewhere have not been able to confirm these findings Senior White (1938) in the Jeypore Hill tracts found that the species bite mainly around m dnight very little at 2 30 a m and none at all at 4 30 a m Observations made at Delhi by Afridi and Puri (1940) were in agreement with those of Senior White Further investigations made in Delhi by Pal (1945) showed that the greatest biting activity of the species took place between 22 30 and 01 00 hours gradually decreasing after midnight

FLIGHT RANGE

Russell *et al* (1944) carried out intensive experiments on the determinat on of the flight range of the species in Madras state They took 207 800 *culicifacies* specimens marked them with Majid s (1937) dusting technique and released them at a central spot Recaptures were made from 80 calf baited traps in concentric circles placed at varying distances The conclusion of their experiments was that the total fl ght range ot the species in Madras was between 1 5 and 1 75 miles

Earlier workers judged the flight range from their observations on the distances traversed by the species from the breeding places to the adult resting places Stephens and Christophers (1902) believed the flight range to be lim ted to only a quarter of a mile at Nagpur At Mianmir near Lahore however Christophers (1904) concluded that the species was probably capable of covering distances of half a mile or more during later part of malaria season Lindberg (1935) regarded the dispersal range in Hyderabad

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Clyde (1931) reported from his observation in U P Terai that the species bite human beings during day as well as night time King and Krishnan (1929) recorded similar observation in Nellore District (Madras) but subsequent workers elsewhere have not been able to confirm these findings Senior White (1938) in the Jeypore Hill tracts found that the species bite mainly around midnight, very little at 2-30 a m and none at all at 4-30 a m Observations made at Delhi by Afridi and Puri (1940) were in agreement with those of Senior White Further investigations made in Delhi by Pal (1945) showed that the greatest biting activity of the species took place between 22-30 and 01-00 hours gradually decreasing after midnight

FLIGHT RANGE

Russell *et al* (1944) carried out intensive experiments on the determination of the flight range of the species in Madras state They took 207 800 *culicifacies* specimens marked them with Majid's (1937) dusting technique and released them at a central spot Recaptures were made from 80 calf baited traps in concentric circles placed at varying distances The conclusion of their experiments was that the total flight range of the species in Madras was between 1 5 and 1 75 miles

Earlier workers judged the flight range from their observations on the distances traversed by the species from the breeding places to the adult resting places Stephens and Christophers (1902) believed the flight range to be limited to only a quarter of a mile at Nagpur At Mianmir near Lahore, however, Christophers (1904) concluded that the species was probably capable of covering distances of half a mile or more during later part of malaria season Lindberg (1935) regarded the dispersal range in Hyderabad

(Deccan) to be 1,100 yards (five furlongs) James (1903) at Mian-mir found it restricted to 600 yards (0 31 miles) only Bose (1934) at Birnagar (Bengal) and Mulligan and Baily (1936) at Quetta (Pakistan) found the dispersal of the species not exceeding half a mile Afridi *et al* (1938) found in Kutch that adult *A culicifacies* remained strictly confined to the immediate neighbourhood of the breeding places

To sum up the findings of different workers it may be said that the flight range of the species is normally about half a mile but may extend up to 1 75 miles when climatic conditions are exceptionally favourable Raghavan and Krishnan (1949) have given evidence of passive transportation by country crafts of *A culicifacies* over long distances along the Buckingham Canal in southern India

ALTITUDE

Although *A culicifacies* is generally reputed to be a plains species, it has been found to occur in some areas at high altitudes also Davy (1912) found it to occur in Quetta area (Pakistan) at altitudes between 5 500 to below 6,500 feet Graham (1912) recorded it at 6,355 feet above sea level in Nainital Mulligan and Baily (1936) established that *A culicifacies* was one of the three important vectors of malaria in Quetta areas at 5 000—6 000 feet altitude Jacob (1950) found that the species is able to transmit the disease in Kashmir only up to an altitude of 4 000 feet Clemeshaw (1927) reports an out break of malaria due to this species at an altitude of 3,000 ft in Travancore The record of highest altitude at which a single specimen of this species was caught is 7,500 feet in Murree hills in Pakistan (Gill 1923) Afridi and Puri (1940) reviewed data from southern India (Malabar and the Nilgiris) to show that at high altitude the species prevails for a shorter period in the pre-monsoon months in contrast to lower altitudes where it occurs for a longer post monsoon period

For chalking out favourite haunts of the species one needs to look for areas with moderate or scarce rainfall rather than altitudes In a hill tract in Mysore State, Brooke Worth (1953) for his studies on the anopheline fauna selected three areas each having an altitude of 3,000 feet but with marked differences in annual rainfall—223, 83.19 and 48 23 inches With regard to *A. culicifacies* he found that

the incidence of the species was extremely low in the high rainfall area as compared to the intermediate and low rainfall areas

HIBERNATION AND AESTIVATION

Neither of these two phenomena seem to occur in the life of *A culicifacies* in any part of the plains of India Covell and Baily (1930) believed that there is a period of aestivation in the life of this species when the temperatures are above 90°F But no supporting evidence has been found by any subsequent workers In Delhi area which has very hot summer and severe cold winter months this species remains active throughout the year though there are marked fluctuations in their numerical prevalence This is based on the following observations made by us under field conditions extending over a number of years —

(a) All stages of this species *viz* larvæ pupæ and adults are found throughout the year

(b) Blood fed females are available all through the year

(c) Ovaries in all stages of development are observed in wild caught specimens in all the months

(d) Oviposition has been obtained from the wild caught gravid females in the hottest as well as the coldest months of the year

Venkat Rao (1947) showed that in *A culicifacies* there exist a phenomenon of gonotrophic discordance in which some females required more than one blood meal for the maturation of the ovaries

It is well known that certain percentage of mosquitoes may not be able to take a complete blood meal during the course of a single night and another blood meal is taken the following night to mature their ovaries This has been fully discussed by Jaswant Singh and Mohan (1951)

ANTHROPOPHILIC INDEX

Results of large number of precipitin tests on blood samples from *A culicifacies* collected from the different parts of the country have been recorded by various workers These are presented in Table I It will be seen that the species is predominantly zoophilic

TABLE I

Anthropophilic index

S No	Investigator	Place	Year	Anthropophilic index per cent		Remarks epidemic or non epidemic year
				On positive reaction	On total examined	
1	*Afridi Jaswant Singh and Harwant Singh (1939)*	*Delhi*	1937	1 8		*N ep**
2	do	Delhi	1938	9 93		N ep.
3	Barber and Rice (1938)	Poona	1937	1 9		N ep
4	Covell and Jaswant Singh (1943)	Delhi	1942	22 3	20	Ep.
5	M I I Report (1948 50)	Tirumalapur Hyderabad Dn)	1946 and 48		24	N ep
6	do	Bellary (Madras)	1948		10	N ep
7	do	Mun rabad (Madras)	1949 50		32	N ep
8	do	Haldwani (U P)	1950		50	N ep
9	do	Chieng Mai (Thailand)	1949		51 7	N ep
10.	Ramsay Chandra and Lamprell (1936)	Assam and N Bengal	1936	47 3	29 0	N ep
11	Russell and Jacob (1939)	Ennore (Nellore Coastal area)	1937 38	80 0	34 0	N ep
12	Russell Menon and Rao (1938)	Pattukottai	1937 38	0 25	0 15	N ep
13	Russell and Rao (1942)	-do	1942	2 5	1 30	N ep
14	*Senior White (1947)*	*East and Central India (Singhbhum Chatikona Korea and Vizagapatam*	*1947*	12 9		N ep
15	Senior White and Venkat Rao (1943)	Vizagapatam	1943	10 1		N ep
16	do	Jeypore hills	1938 43	25 9		N ep

* Ep=Epidemic
N ep =Non epidemic.

MAXILLARY INDEX

Roubaud (1921) was the original propounder of the theory regarding the blood preferences of anophelines in relation to the number of teeth present on their maxillæ The critical figure for *the maxillary index (average number of teeth on the maxilla)* was fixed by him at 14 He claimed that an index of 14 or less was associated with human blood preference and 14 and above indicative of cattle blood preference Considerable controversy exists regarding this claim and literature on the subject has been well reviewed by Senior White (1937*a*) Maxillary index of *A culicifacies* was found by him to be 12 9 for the country as a whole Of the 200 maxillæ examined the number of maxillæ in different detention groups were as follows —

Dentition		*Number of maxillæ*
below	10	0
	10	1
	11	16
	12	60
	13	67
	14	43
	15	13
above	15	0

Similarly Pal (1945 *b*) found the index at Delhi to be 12 6 Certain amount of bilateral asymmetry does occur in the number of teeth on the pair of maxillæ of the individual mosquito specimens

A comparison of the maxillary index of *culicifacies* from human baited traps and buffalo baited traps at Vizagapatam showed no significant difference In the former it was 13 2 and latter 13 3 (Senior White and Rao, 1943) Furthermore Russel and Rao (1942) found that there was no difference in the maxillary indices of this species caught from malarious (Pattukottai) and non-malarious (Tanjore Delta) areas In the former, the index was 11 79 and in the latter 11 87

Although paucidentate, (index less than 14) we know that the species is predominantly zoophilic which is at variance with

Roubaud's theory Morever there are many species in India which are confirmed *non-vectors but show paucidentate condition*

Therefore the use of this index seems to be of very little aid, at any rate in the case of *A culicifacies*, either in determining its food preference or its vectorial status

The suggestion made by Roubaud Toumanoff and Gaschen (1933) that the working out of maxillary index is more valuable than actual discovery of infections among mosquitoes cannot be accepted at least so far as *A. culicifacies* is concerned

RELATION TO MALARIA

Christophers (1933) was of opinion that *A culicifacies* could be regarded as an important vector wherever it was found It was, however, disapproved by Senior White (1937, 38) who showed that it did not take any part in malaria transmission in the highly endemic regions of Jeypore Hill tracts and other large areas of East Central India where it is found in large numbers The species occurs throughout the country but its vectorial capacity is limited to Peninsular and North Western India In Ceylon this is the only vector It is to be found in small numbers in Burma Thai land, Indo China and South China and is not considered to be a vector of any importance A single specimen with oocysts in the gut found at *Lahati, Yunan led to its being considered as suspected* vector in that area (Gaschen 1931) In the westerly direction the vectorial capacity of the species extends through Afghanistan to perhaps Muscat in Arabia It is also suspected as a carrier in the *vicinity of Aden* (Covell, 1931)

The species is notorious as the causative agent of regional malaria epidemics of great severity and wide rage It is well known as an efficient vector of *P vivax* and *P falciparum* infections in nature Siddons (1944) proved by experimental transmissions that the species can be efficient carrier of *P malariae* infections as well The work of Russel Menon and Rao at Pattukottai (1938) also shows that the species is responsible for the transmission of all three species of plasmodia

Senior White (1940) has reviewed the dissection records of this species in different localities in India to show the distribution of its vectorial status Subsequently more areas have been surveyed and information available is presented below in a tabular form

TABLE II

Dissections records of A culicifaces

Serial No	Author and year		Locality	Dissection period	Number dissected	Sporozoite rate per cent	Oocyst rate per cent	Remarks
1	2		3	4	5	6	7	8
1	Cornwall	(1902)	Ennore		25	16 0	0 0	
2	Stephens and Christophers	(1942)	Mian Mir (Pakistan)	Oct	252	4 0	0 0	
3	*Idem*	(1902)	Ennore		69	8 6	0 0	
4	Graham	(1910)	Kosi (Indus)	Oct	134	1 5	3 3	
5	*Idem*	(1910)	Kairana	Sept Oct	128	0 0	1 3	
6	Ross	(1912)	Ennore	Feb May	85	1 2	0 0	
7	James and Gunasekara	(1913)	Tala mannar	April	36	2 1	0 0	
8	*Graham*	*(1913)*	*Meerut*	*Octo Nov*	211	0 0	0 5	
9	Ross	(1913)	Cuddapah	July Dec	200	0 0	1 0	
10	Horne	(1914)	Penukonda	Nov Dec	16	6 3	0 0	
11	Hodgson	(1914 15)	Delhi	Probably July Aug Sep	110	0 0	2 7	
12	Mhaskar	(1915)	N Kanara	Jan Dec	837	0 2	0 7	
13	Rao	(1915)	Hospet	Nov Dec	116	1 7	0 0	
14	*Idem*	(915)	Ramnad	Jan Feb	44	0 0	4 5	

1	2	3	4	5	6	7	8
15	Sinton (1917)	Kohat	July-Sep.	40	0 0	2 5	Positive found only in September.
16	Krishnan (1925)	Vizagapatam	Nov	31	0 0	3 3	
17	Sinton (1925)	Mani Majra	June	6	0 0	16 6	
18.	Ayer (1925)	Sappal Hill	Apr -May	98	1 0	0 0	
19	Feegrade (1927)	Hsipaw (Assam-Burma)	June-Oct.	113	0 0	0 8	
20.	Ayer (1927)	Bimlipatam	Sep.	37	0 0	10 3	
21.	Mayne (1927)	Saharanpur	Apr -Sep	2021	0 1	0 1	
22.	Gale (1928)	Mawlaik (Burma)	June-Sep	32	0.0	3 1	
23.	Carter and Jacocks (1929)	Chilow (Ceylon)	Dec -Jan.	336	6 5	1 5	
24	*Idem.* (1929)	Karande (Ceylon)	July	267	9 7	6 4	
25.	King and Krishnan (1929)	Udayagiri	Apr.	42	2 4	9 5	
26.	Venkataraman (1929)	Vizagapatam	Aug.	186	0 0	1 6	
27	Carter and Jacocks (1929)	Ridigama (Ceylon)	Nov.	558	0 9	2 2	
28.	Baily (1929)	Shikarpur (Pakistan)	Aug -Oct -Nov.	52	1 9	11 5	
29.	Covell and Baily (1929)	Sukkur (Pakistan)	Sep	74	5 4	9 5	
30.	Rao (1929)	Nandyal	Jan -Feb	68	1 5	1 5	
31.	King and Iyer (1929)	Mopad	Now.	297	1 4	6 1	
32.	Young and Majid (1930)	Larkana (Pakistan)	Oct -Jan.	186	1 1	0 5	
33.	Covell and Baily (1930)	Larkana (Pakistan)	Aug Apr	785	2 7	19 7	
34.	Carter (1930)	Chilaw (Ceylon)	25 months	2294	2 6	1 2	
35	Feegrade (1930)	Purinbyu (Dooars Salween)	July-Oct	41	0 0	2 2	

1	2		3	4	5	6	7	8
36	Freegrade	(1930)	Mazli (Burma)	July Oct	271	3 8	1 1	
37	*Sweet and Rao*	(1931)	Kolar (Mysore)	June	4	50 0	0 0	Epidemic
38	*Idem*	(1931)	Mysore State	Oct 1928 Dec-1930	5635	*0 124*	*0 018*	The *epidemic* infection index was 31 25 per cent in 16 dissections
39	*Idem*	(1931)	Mysore City	Aug 1930	10	10 0	0 0	Epidemic
40	Covell and Baily	(1932)	N Sind (Pakistan)		*649*	*11 8*	*19 2*	Epidemic
41	Nursing Sweet and Rao	(1934)	Nagenhalli	Mar Apr 1933	271	0 0	1 5	Transmission Mar to June
42	*Idem*	(1934)	Hariyur	Nov Dec 1932 33 Oct Nov 1932	447	0 44	3 6	Transmission Nov Dec
43	*Idem*	(1934)	Mandya	Apr-Aug Sep 1933	1151	1 0	2 3	Epidemic Transmission throughout the year Mar during two periods *112* Mar June & Oct Dec
44	Covell and Baily	(1934)	Larkana (Sind)	Aug 1928 Apr 1933	6905	2 475		Highest sporozoite rate was 13 7% in Nov 1929 during and epidemic
45	Nursing Sweet and Rao	(1934)	Mysore	1932 33	1964	0 714	2 34	Inclusive of epidemic areas
46	Freegrade	(1934)	Maymyo (Burma)	July Aug	206	0 0	0 5	
47	Iyengar	(1934)	Kulasekaram	Feb Sep	*984*	*0 102*	0 0	

1	2		3	4	5	6	7	8
48.	Ahuja	(1934)	Ajmer	Aug -Sep	53	3 8	7 5	Transmission July-Oct
49	Covell Baily and Prasad	(1935)	Sind	Aug -Dec 1930-33	5815	1 59	2 59	
50	Bierchiffe	(1935)	Maha oya Basin (Ceylon)	Nov -May	2482	4 7	3 8	Epidemic
51	*Idem*		Mahawabi G Basin (Ceylon)	Nov -May	399	2 5	4 0	Epidemic
52.	*Idem*	(1935)	Deduran oya Bain (Ceylon)	Nov -May	966	3 2	2 1	Epidemic.
53	Mulligun and Baily	(1936)	Quetta (Pakistan)	July Oct	835	3 23	2 99	Transmission July-Oct
54	Viswanathan	(1936)	Madakasira	April 1934	70	2 8	2 8	Epidemic year Transmission throughout the year with peaks in Apr and Nov
55	Lamprell	(1936)	Lumding (Assam)	June Aug	516	0 8	0 0	
56	Senior White	(1937)	Chatikona (Orissa)	Oct '05 Sep '36	1168	0 0	0 2	Ist Sept -Dec
57.	Senior White	(1937)	Jeypore Hills	Oct '35-Sep '36	4744	0 0	0 06	
58	Hicks and Majid	(1937)	Karnal Punjab	July 1931 Jan 1936	8850	0 6	0 227	Transmission July-Nov Max during Aug -Sept
59	Sweet	(1937)	T Narsipur (Mysore)	June 1931-Jan 1936	1191	0 7	3 8	
60	Niogi and Khan	(193£)	Sylee (Dooar) N Bengal)	6 years	124	0 8	0 0	No epidemic known in this area
61	Senior White	(1937)	Lanjigarh Road (Jeypore Hills)	Oct 1936 Sep 1937	1067	0 00	0 09	

1	2		3	4	5	6	7	8
62	Ramsay	(1937)	Dharbanga	16 months	2988	0 07	0 07	
63	Russell *et al*	(1938)	Pattukkottai	18 months	6483	0 08	0 07	Transmission Aug-January
64	Barber and Rice	(1938)	Poona	Mar-July 1937	874	0 4	0 0	Transmission July-Oct.
65	Senior White and Das	(1938)	Singhbhum Hills	1935-1938	1611	0 0	0 31	
66	Covell *et al*	(1938)	Delhi	July Oct 1937	1028	0 097	0 097	
67	Senior White	(1938)	Jeypore Hills	Oct 1936 Sep 1937	2446	0 0	0 082	
68	Ramsay	(1938)	Peermade	31 months	401	2 0	3 5	
69	Russell and Jacob	(1939 a)	Ennore	May 1939 June 1938	984	0 1	0 7	
70	Sundaresan	(1939)	Baruva (Orissa)	Aug to Dec	122	0 0	0 8	
71	Mathew	(1939)	Travancore	Aug 37 to Aug, 38	1131	0 3	0 5	
72	Russell and Rao	(1940-a)	Pattukkottai	Nov 1936 Jan '40	13145	0 061	0 073	
73	Senior White	(1940)	Chota Nagpur ranges	1937 1940	7482	0 0	0 2	
74	*Idem*	(1940)	Kesinga (Orissa)	June Dec 1936	129	0 0	0 8	
75.	*Idem*	(1940)	Khodri (Satpura Ranges)	1938 39	700	0 0	0 1	
76	*Idem*	(1940)	Khongsara (Satpura Ranges	1938-39 (26 months)	1317	0 0	0 15	
77	*Idem*	(1940)	Balghara	1938-39 (1 year)	541	0 0	0 1	
78	*Idem*	(1940)	Bhadrak (Orissa)	1931-40 (31 months)	119	0 0	0 8	
79	*Idem*	(1940)	*Paniyajobi*	July 1936-Dec 1977	425	0 0	0 2	
80.	*Idem*	(1940)	Bhanwar Tonk (Satpure Ranges)	1938 39 (1 year)	426	0 2	0 2	
81.	Viswanathan	(1941)	Lumding (Assam)	1931 1940	1232	0 4	0 16	Active transmission March November

1	2	3	4	5	6	7	8
82	Rao and *Biswas* (1942)	Dharamjoi Garh (M P)	Aug to Nov 1941	969	0 5	0 0	
83	Senior White and Venkata Rao (1943)	Vizagapatam	1940 1943	6608	0 015	0 05	
84	Covell and Jaswant Singh (1943)	Delhi	July Nov 1942	9628	0 2	0 2	Epidemic
85	De Burca (1946)	Jubbalpore	Feb Sep 1943				
86	*Idem* (1946)	Mhow	August 1944	166	2 4	2 4	
87	Senior White (1946 a)	Dongargarh (Satpura Ranges)	Aug Sep Oct 1943	258	0 38	0 38	
			1937 1944	4816	0 02	0 02	Transmission season Aug Nov
88	Raghavan and Krishnan (1949)	Shrihnr kottaIsland (Andhra State)	Feb Aug 1948	54	1 8	1 8	
89	Subramanian and Gupta (1950)	Dharamjaigarh (M P)	June 1949 Dec 1950	2277			
90	Jacob (1950	Jammu	1948 1949	1021	0 27	0 27	Transmission July Sep
91	Viswanathan (1950)	Thana (Bombay)					
		Ahmadabad	1347 1948	737	0 27	0 57	
		Kaira	1947 1948	1343	0 075	0 075	
		B japur	1947 1948	3463	0 44	0 275	
		Poona	May June 1944	400	0 25	0 25	
		Nasik	1948 1949	10057	0 01	0 01	
		East Khandesh	1948 1949	2786	0 0	0 0	
92	Krishnan (1955)	Vindhya Pradesh	1954	5246	0 0	0 0	
93	Sharma (1955)	Madhya Bharat	1954	2202	0 0	0 0	Infected specimen in Sep 1954

OTHER INFECTIONS

Two specimens of *A culicifacies* infected with both malaria and filarial infections have been recorded by Russell and Jacob (*1939 a*) at Ennore There being no filaria in Ennore it was presumed that labourers (woodcutters) from Sri Harikotta Islands working temporarily at Ennore supplied the source of infection In Nasik District of Bombay State, Viswanathan (1950) found in a salivary glands preparation of *A culicifacies* a trypanosome in all stages of development along with plasmodial sporozoites. He gave the name *Trypanosoma kalwanensis* to it Nematode infections in larvæ as well as adults of *culicifacies* in Ceylon have been recorded by Carter Rustomjee and Saravanamuttu (1927) Sinton (1917) found encysted *trematodes* in adult A *culicifacies* at Kohat (Pakistan) This trematode has been named *Agamodistomum sintoni* Van Thiel, 1922 Worms belonging to the genus *Mermis* (Mermithidæ) entangled in the malpighian tubules of *A culicifacies* females have been recorded by Sinton (*1932*) Micro organisms termed 'pseudosporozoites belonging to the family *Chytridinæ* of fungi have also been recorded in fresh salivary gland preparations *A culicifacies* (Bhatia *et al*, 1953)

CONTROL

The breeding of this species has been very successfully controlled by naturalistic methods like the herbage cover in Madras (Russell and Jacob, 1939 *a*, Russell and Knipe 1942) With the pyrethrum spray killing, excellent control was obtained against *A culicifacies* in Delhi (Covell 1941) and in South India (Russell and Knipe 1939, 1940, 1941) The results obtained were particularly good because this species spends most of its time during its gonotrophic cycle indoors and is thus amenable to indoor spraying Though effective control was obtained by space-spraying once a week, yet Covell and Jaswant Singh (1943) are of opinion that during an epidemic where *A culicifacies* is the vector, daily spraying will have to be resorted to, to get very effective results Senior White (1945) comparing the relative efficacy of DDT and pyrethrum against *A culicifacies* came to the conclusion that DDT residual spray brought down 81 per cent reduction in *A culicifacies* while pyrethrum space spray twice a week could bring it down to only 49 per cent With the country-wide use of residual insecticides *A culicifacies* has been controlled to a very great extent, and malaria in such treated areas will soon cease to be a major public health problem (Rao, 1948, Viswanathan, 1950, Jawant Singh *et al*, 1951)

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DISSECTION RECORDS OF WILD CAUGHT ANOPHELINE MOSQUITOES OTHER THAN THE REPUTED VECTORS OF MALARIA

BY

B L. WATTAL

(Malaria Institute of India, Delhi)

[May 10, 1957]

APART from the principal vectors of malaria in different parts of the country, one often needs to know the malaria transmission potentialities of other anophelines encountered in a given area In order to fulfil this requirement all available information on the dissection results of *anophelines* by different workers is summarised specieswise in a tabular form hereunder Data shown in the Table are according to periods of study Figures for earlier periods are at the top followed by those of later in a descending order

Legends : G—Gut
Gl—Gland

1 *Anopheles Aconitus*, Donitz, 1902

Locality	Reference	No Dissected G/Gl	No Pos G/Gl	Per cent Positive G/Gl	Infection		Remarks
1	2	3	4	5	6	7	8
Cachar Assam Apr Dec 1927	Strickland 1929	136	0/0	0/0	0	0 0	Total/ Per cent
Mysore	Sweet 1929-30	62	0/0	0/0	0	0 0	
Cachar Assam Apr 1927-Mar 1930	Bombay 1930	1661	0/0	0/0	0	0 0	
Jorhat Assam	Ramsay 1931	175	0/0	0/0	0	0 0	
Assam 1931 41	Vishwanathan 1941 *et al*	1145	1/0	*0 09/0	*1	0 09	*Calculated figures
W Bengal 1933 40	Sen 1948	80	0/0	0/0	0	0 0	
Coastal Orissa 1935-41	Senior White 1943 *et al*	951	3/2	*0 3/0 2	*5	0 5*	*Calculated figures
Singhbhum Hills Sept 1955-Jan 1937	Senior White 1938 and Das	27	0/0	0/0	0	0 0	
Tanjore Madras Nov 1936 Jan 1940	Russell and Rao 1940	46	0/0	0/0	0	0 0	
Satpura Ranges 1936 40	Senior White 1939 and Adhikari	481	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Jeypore Hills Oct 1936-37	Senior White 1938	9	0/0	0/0	0	0 0	
Hazari Bagh 1936-1943	Senior Whitei 943	11	0/0	0/0	0	0 0	
Bengal Nov 1937-38	Iyengar 1939	894	0/0	0/0	0	0 0	
Bally Calcutta Aug 1937 July 1938	*Roy 1939*	9	0/0	0/0	0	0 0	
Chilka Lake April 1937 Mar 1938	Senior White 1939 and Adhikari	481	1/0	*02/0	*1	0 2*	*Calculated figures i
Jeypore Hills	Senior White 1937	107	1/0	*0 9/0	*1	*0 9	*Calculated figures
Wynaad 1938-39	*Covell and* *1939* Harbhagwan	2940	0/0	0/0	0	0 0	
Darjeeling June Nov 1938	Gilroy 1939	33	0/0	0/0	0	0 0	
Singhbhum Hills May 1938-Apr 1940	Senior White 1940 and Narayana	7	0/0	0/0	0	0 0	
Coastal Orissa Apr 1939-Mar 1942	Covell and Singh 1942	674	0/0	0/0	0	0 0	
Bengal 1939	Iyengar 1940	1494	0/0	0/0	0	0 0	
Deltaic Bengal 1939-41	*Idem* 1944	1339	0 0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Nizamabad 1940-42	Abraham and Samuels 1944	148	0/0	0/0	0	0 0	
Nilgiris Feb. 1940 Jan 1941	Russell and Jacob 1942	2	0/0	0/0	0	0 0	
Assam 1940-41	Vishwanathan *et al.* 1941	254	1/0	0 4/0	*1	*0 4	*Calculated figures
Waltair Sept, 1940 Dec. 1941	Senior White and Rao 1943	35	0/0	0/0	0	0 0	
Darjeeling 1941	Khan 1942	44	0/0	0/0	0	0 0	
Udaipur, M P. Aug-Nov 1941	Roy and Biswas 1942	1	0/0	0/0	0	0 0	
Madras 1942-44	Roy *et al.* 1946	10	0/0	0/0	0	0 0	
Jeypore Hills Mar, 1942-Feb 1943	Senior White *et al.* 1945	68	1/0	*1 5/0	*1	*1 5	*Calculated figures
Madras Orissa, Coast, Mar 1943 Dec 1945	Senior White *et al.* 1947	219	0/0	0/0	0	0 0	
East Central India 1944-45	Senior White 1946	12	0/0	0/0	0	0 0	
Bissamcuttack Area 1944 46	Senior White and Ghosh 1946	103	0/0	0/0	0	0 0	
Damodar-Hoogly River Basin	Jafar and Iyenger 1947	172	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
	2 *Anopheles Aitkeni*, James 1903						
Cachar Assam Apr 1927-Mar1930	Ramsay 1930	6	o/o	o/o	o	o o	
Cachar Apr-Dec 1927	Strickland 1929	3	o/o	o/o	o	o o	
	3 *Anopheles Annandalei*, Baini Prashad 1918						
No record of dissections available							
	4 *Anopheles Annularis*, Van der Wulp, 1884						
Vector species							
	5 *Anopheles Barbirostris*, Van der Wulp, 1884						
Bengal	Stephens and Christophers 1902	2	o/o	o/o	o	o o	
Bengal	Fry 1914	23	o/o	o/o	o	o o	
Cachar, Assam Apr Dec 1927	Strickland 1929	2	o/o	o/o	o	o o	
Mysore	Sweet 1929-30	26	o/o	o/o	o	o o	
Cachar Apr 1927 Mar 1930	Ramsay 1930	26	o/o	o/o	o	o o	
Assam	Manson 1931	11	o/o	o/o	o	o o	
Bengal 1933-40	Sen 1948	80	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Tanjore-Madras Nov 1936 Jan 1940	Russell and Rao 1940	21	o/o	o/o	o	o o	
Bengal Nov 1937 38	Iyengar	12	o/o	o/o	o	o o	
S Travancore Aug 1937 38	Mathew 1939	1	o/o	o/o	o	o o	
Bally Calcutta Aug 1937 July 1938	Roy 1939	43	o/o	o/o	o	o o	
Ennore Nellore May 1937 June 1938	Russell and Jacob 1939	22	o/o	o/o	o	o o	
Chilka Lake Apr 1937-Mar 1938	Senior White and Adhikari 1939	3	o/o	o/o	o	o o	
Wynaad 1938 39	Covell and Harbhagwan 1939	19	o/o	o/o	o	o o	
Jharia Bihar Apr 1938 Sept 1940	Rao 1941	8	o/o	o/o	o	o o	
Bengal, 1939	Ivengar 1940	44	o/o	o/o	o	o o	
Deltaic Bengal 1939 41	*Idem* 1944	49	o/o	o/o	o	o o	
Nilgiris Feb 1940 Jan 1941	Russell and Jacob 1942	1	o/o	o/o	o	o o	
Assam 1940 41	Vishwanathan *et al* 1941	89	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Kurnool Anantapur Cuddaph 1942-44	Rao *et al* 1946	14	0/0	0/0	0	0 0	
North Kanara May 1942-43	Singh and Jacob 1944	37	0/0	0/0	0	0 0	
Damodar-Hoogly-Basin	Jafar and Iyengar 1947	2	0/0	0 0	0	0 0	
Nellore Madras Feb - Aug, Dec, 1948	Raghavan and Krishnan 1949	3	0/0	0/0	0	0 0	
Udaipur, Raj July Dec., 1949	Subramanian and Gupta 1950	42	0/0	0/0	0	0 0	

6 *Anopheles Bariensis*, James 1911

No dissection records avalnble

7 *Anopheles Culicifacies*, Giles 1901

Vector species

8 *Anopheles Culiciformis*, Cogill 1903

No dissection records available

9 *Anopheles Fluviatilis*, James 1902

Vector species

1	2	3	4	5	6	7	8
	10 *Anopheles Gigas*, Giles 1901						
Assam 1940-41 .	Vishwanathan *et al.* 1941	18	0/0	0/0	0	0 0	
Nilgiris Feb 1940-Jan 1941	Russell and Jacob 1942	5	0/0	0/0	0	0 0	
	11. *Anopheles Hyrcanus* var *Nigerrimis* Giles 1900						
Calcutta	Stephens and Christophers 1902 (a)	8	0/0	0/0	0	0 0	
Meerut	Graham 1911	22	0/0	0/0	0	0 0	
Bengal	Fry, 1914	66	0/0	0/0	0	0 0	
Kanara	Mhaskar* 1914	7	0/0	0/0	0	0 0	*Reported by Covell 1927
Krishnagar Bengal	Sur and Sur 1929	190	0/0	0/0	0	0 0	
Birnager Bengal	*Idem* 1929	74	0/0	0/0	0	0 0	
Cachar Assam Apr-Dec. 1927	Strickland 1929	1757	0/0	0/0	0	0 0	
Cachar Apr. 1927-Mar. 1930	Ramsay, 1930	5461	0/0	0/0	0	0 0	
Jorhat Assam	*Idem* 1931	209	0/0	0/0	0	0 0	
W. Bengal 1933-40	Sen, 1948	610	0/0	0/0	0	0 0	
Tanjore: Madras Nov 1936-Jan. 1940	Russell and Rao 1940	436	0/0	0/0	0	0 0	
S. Travancore	Mathew 1939	3	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
	10 *Anopheles Gigas*, Giles 1901						
Assam 1940-41	Vishwanathan *et al* 1941	18	0/0	0/0	0	0 0	
Nilgiris Feb 1940 Jan 1941	Russell and Jacob 1942	5	0/0	0/0	0	0 0	
	11 *Anopheles Hyrcanus* var *Nigerrimis* Giles 1900						
Calcutta	Stephens and Christophers 1902 (a)	8	0/0	0/0	0	0 0	
Meerut	Graham 1911	22	0/0	0/0	0	0 0	
Bengal	Fry, 1914	66	0/0	0 0	0	0 0	
Kanara	Mhaskar* 1914	7	0/0	0/0	0	0 0	*Reported by Covell 1927
Krishnagar Bengal	Sur and Sur 1929	190	0/0	0/0	0	0 0	
Birnager Bengal	*Idem* 1929	74	0/0	0/0	0	0 0	
Cachar Assam Apr-Dec 1927	Strickland 1929	1757	0/0	0/0	0	0 0	
Cachar Apr 1927-Mar 1930	Ramsay, 1930	5461	0/0	0/0	0	0 0	
Jorhat Assam	*Idem* 1931	209	0/0	0/0	0	0 0	
W Bengal 1933-40	Sen, 1948	610	0/0	0/0	0	0 0	
Tanjore · Madras Nov 1936-Jan 1940	Russell and Rao 1940	436	0/0	0/0	0	0 0	
S Travancore	Mathew 1939	3	0/0	0/0	0	0 0	

1	2	3	4	5	9	7	8
Aug 1937-38							
Bengal 1937-38	Iyengar 1939	405	o/o	o/o	o	o o	
Bally Calcutta	Roy 1939	129	o/o	o/o	o	o o	
Aug 1937-38							
Ennore-Nellore	Russell and Jacob 1939	9	o/o	o/o	o	o o	
May 1937-June 1938		(2/9)					
Wynaad	Covell and 1939	90	o/o	o/o	o	o o	
1938-39	Harbhagwan						
Jharia Bihar	Rao 1941	20	o/o	o/o	o	o o	
April 1938-Sept. 1940							
Bengal 1939	Iyengar 1940	727	o/o	o/o	o	o o	
Chilka Lake	Senior White	50	o/o	o/o	o	o o	
1939	and Adhikari 1939						
Deltaic Bengal	Iyengar 1944	480	o/o	o/o	o	o o	
1939-41							
Assam 1940-41	Vishwanathan	161	o/o	o/o	o	o o	
	et al 1941						
Nilgiris	Russell and Jacob 1942	38	o/o	o/o	o	o o	
Feb. 1940-Jan. 1941							
Nizamabad	Abraham and	106	o/o	o/o	o	o o	
1940-42	Samuels 1944						

1	2	3	4	5	6	7	8
Kurnool, Anantpur and Cuddapah 1942 44	Rao *et al* 1946	138	0 0	0 0	0	0 0	
North Kanara May 1942-May 1943	Singh and Jacob 1944	72	0/0	0/0	0	0 0	
Damodar Hooghlo Basin	Jafar and Iyengar 1947	72	0/0	0/0	0	0 0	
Nellore Feb -Aug and Dec 1948	Raghavan and 1939 Krishnan	7	0/0	0/0	0	0 0	
Udaipur, Raj July-Dec 1949	Subramanian and Gupta 1950	286	0/0	0/0	0	0 0	
12 *Anopheles Insulaeflorum*, Swell and Swell							
No dissection records available							
13 *Anopheles Jamesi*, Theobald 1901							
Cachar Assam April-Dec 1927	Strickland 1929	8	0/0	0/0	0	0 0	
Mysore	Sweet 1929-30	216	0/0	0/0	0	0 0	
Cachar Apr 1927-Mar 1930	Ramsay 1930	162	0/0	0/0	0	0 0	
Orissa Coastal Plain 1935 41	Senior White *et al* 1943	20	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Jeypore Hills	Senior White 1937	2	0/0	0/0	0	0 0	
Tanjore Madras Nov 1936-Jan 1940	Russell and Rao 1940	305	0/0	0/0	0	0 0	
Satpura Ranges 1936-40	*Senior White 1940	140	0/0	0/0	0	0 0	*Reported by Kenrik
		6	0/0	0/0	0	0 0	1915
Hazaribagh 1936-43	*Idem* 1943	10	0/0	0/0	0	0 0	
Ennore Nellore May 1937-38	Russell and Jacob 1939	10 (8/10)	0/0	0/0	0	0 0	
S Travancore Aug 1937 38	Mathew 1939	23	0/0	0/0	0	0 0	
Bengal Nov 1937-38	Iyengar 1939	3	0/0	0/0	0	0 0	
Wynaad Madras 1938 39	Covell and Harbhagwan 1939	1749	0 0	0/0	0	0 0	
Singhbhum May 1938-April 1940	Senior White and Narayana 1940	2	0 0	0 0	0	0 0	
Darjeeling June Nov 1938	Gilroy 1939	10	0 0	0 0	0	0 0	
Bengal, 1939	Iyengar 1940	3	0 0	0 0	0	0 0	
Nilgiris Feb 1940 Jan 1941	Russell and Jacob 1942	94	0 0	0 0	0	0 0	
Waltair	Senior White and	2	0 0	0 0	0	0 0	

1	2	3	4	5	6	7	8
Sept. 1940 Dec 1941	Rao 1943						
Nizamabad 1940-47	Abraham and Samuels 1944	2	o/o	o/o	o	o o	
North Kanara May 1942-May 1943	Singh and Jacob 1945	653	o/o	o/o	o	o o	

14. *Anopheles Jeyporiensis*, James 1902

Vector species.

15. *Anopheles Karwari*, James 1903

1	2	3	4	5	6	7	8
Cachar : Assam Apr -Dec. 1927	Strickland 1929	1697	1/o	o5/o*	1*	o o5*	*Calculated figures
Mysore	Sweet 1929-30	40	o/o	o/o	o	o o	
Cachar Apr. 1927-Mar. 1930	Ramsay 1930	9252	o/o	o/o	o	o o	
Coastal Orissa 1935-41	Senior White *et al.* 1943	1	o/o	o/o	o	o o	
Hazaribagh 1936-43	Senior White 1943	2	o/o	o/o	o	o o	
Satpura Ranges 1936-40	Senior White and Adhikari 1940	2	o/o	o/o	o	o o	
S. Travancore Aug. 1937-Aug. 1938	Mathew 1939	5	o/o	o/o	o	o o	
Bengal	Iyengar 1939	10	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Nov 1937-Nov 1938							
Wynaad 1938-39	Covell and	8	o/o	o/o	o	o o	
	Harbhagwan 1939						
Nilgiris	Russell and Jacob 1942	8	o/o	o/o	o	o o	
Feb 1940-Jan 1941							
Darjeeling 1941	Khan 1942	2	o/o	o/o	o	o o	
North Kanara	Singh and Jacob 1944	310	o/o	o/o	o	o o	
May 1942 May 1943							
Udaipur Raj	Subramanian and	2	o/o	o/o	o	o o	
July-Dec 1949	Gupta 195c						
	16 *Anopheles Koghi*, Donitz 1901						
Cachar Assam	Strickland 1929	535	1/o	o 18 o*	1*	o 18*	*Calculated figures
Apr -Dec 1927							
Cachar	Ramsay 1930	2094	2/o	o o9/o*	2*	o o9*	*Calculated figures
Apr 1927 Mar. 1928							
Bengal	Iyengar 1929	25	o/o	o/o	o	o o	
Nov 1937 Nov 1938							
Bengal 1939	*Idem* 1941	4	o/o	o o	o	o o	
Assam 1940 41	Vishwanathon *et al* 1941	4	o o	o o	o	o o	
	17. *Anopheles Leucosphyrus*, Donitz 1901						
Vector species							

1	2	3	4	5	6	7	8
18 *Anopheles Lindesayi*, Giles 1900							
Darjeeling 1941	Khan 1942	9	0/0	0/0	0	0 0	
19 *Anopheles Maculatus*, Theobald 1901							
Bengal (Calcutta)	Stephens and Christophers 1902 (a)	11	0/0	0/0	0	0 0	
Assam	Short 1924	62	0/0	0/0	0	0 0	
Cachar Assam Apr Dec 1927	Strickland 1929	147	0/0	0/0	0	0 0	
Cachar 1927-30	Ramsay 1930	3374	0/0	0/0	0	0 0	
Banbassa U P	Clyde 1931	60	0/0	0/0	0	0 0	
Assam 1931-41	Anderson and Vishwanathan 1941	8483	24/5	*0 28/0 05	*29	*0 3	*Calculated figures
Satpura Ranges 1936 40	Senior White and Adhikari 1940	12	0/0	0/0	0	0 0	
Hazaribagh 1936-43	Senior White 1943	22	0/0	0/0	0	0 0	
Jeypore Hills	*Idem* 1937	13	0/0	0/0	0	0 0	
Bengal Nov 1937-Nov 1938	Iyengar 1939	69	0/0	0/0	0	0 0	
Wynaad 1938-39	Covell and Harbhagwan 1939	1	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Darjeeling June Nov 1938	Gilroy 1939	12	0/0	0/0	0	0 0	
Assam 1940-41	Vishwanathan *et al* 1941	1573	33/1	*0 8/0 06	*14	0 9	*Calculated figures
Nilgiris Feb 1940 Jan 1941	Russel and Jacob 1942	39	0/0	0/0	0	0 0	
Waltair Sept 1940-Dec 1941	Senior White and Rao 1943	9	0/0	0/0	0	0 0	
Singhbhum Hills May 1938-Apr 1940	Senior White and Narayana 1940	1	0/0	0/0	0	0 0	
Darjeeling 1941	Khan 1942	1725	c/0	0/0	0	c 0	
		197	0/0	0/0	0	0 0	
North Kanara May 1942-May 1943	Singh and Jacob 1944	3	0/0	0/0	0	0 0	
	20 *Anopheles Majidi* McCombie Young and Majid, 1928						
Darjeeling June-Nov 1938	Gilroy 1939	2	0/0	0/0	0	0 0	
Wynaad 1938 39	Covell and Harbhagwan 1939	72	0/0	6/0	0	0 0	
Nilgiris Feb 1940 Jan 1941	Russell and Jacob 1942	28	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Vector species	21 *Anopheles Minimus*, Theobald, 1901						
	22. *Anopheles Moghylensis*, Christophers, 1924'						
	Kenrick 1914	43	0/0	0/0	0	0 0	
	23 *Anopheles Multiclor*, Cambouliu, 1902						
No dissection records available							
	24, *Anopheles Pallidus*, Theobald, 1901.						
Krishnagar Bengal	Sur and Sur 1929	1232	†0/3	*0/0 2	*3	*0 2	*Calculated figures.
Birnagar . Bengal	*Idem* 1929	234	0/0	0/0	0	0 0	
Mysore	Sweet 1929-30	82	0/0	0/0	0	0 0	
Birnagar : Bengal	Bose 1931	403	1/0	*0 2/0	*1	*0 2	*Calculated figures,
W Bengal 1933-40	Sen 1948	28	0/0	0/0	0	0 0	
Coastal Orissa	Senior White 1943	1409	1/0	*0 07/0	*1	*0 07	*Calculated figures
1935-41	*et al.*	36	0/0	0/0	0	0 0	
Birbhum	Timbres 1935	27238	0/9	*0/0 03	*9	*0 03	*Reported by Kenrick 1915
Birbhum	Iyengar 1939	254	2/0	*0 8/2	*2	*0 8	*Calculated figures.
Jeypore Hils	Senior White 1938	14	0/0	0/0	0	0 0	
Oct 1936-Sept 1937							
Tanjore Madras 1936-40	Russell and Rao 1940	108	0/0	0/0	0	0 0	

† Erroneously reported as 3 gut infections instead of glands by Covell, 1944 and Horsfall, 1955

1	2	3	4	5	6	7	8
Satpura Ranges	Senior White 1946	3157	4/0	*0 13/0	*4	*0 13	*Calculated figures
Jeypore Hills	Senior White 1937	68	0/0	0/0	0	0 0	
Hazaribagh 1936 43	Senior White 1943	3819	0/0	0/0	0	0 0	
Ennore Nellore May 1937 June 1938	Russell and Jacob 1939	19 (14/19)	0/0	0/0	0	0 0	
Bally Calcutta Aug 1937 July 1938	Roy 1939	1	0/0	0/0	0	0 0	
Bengal Nov 1937 38	Iyengar 1939	508	*/20	0 5/0*	*2	0 5*	*Calculated figures
Chilka Lake Apr 1937 Mar 1938	Senior White and Adhikas 1939	15	0/0	0/0	0	0 0	
Singhbhum Hills 1938	Senior White 1938	322	0/0	0/0	0	0 0	
Singhbhum Hills 1938 1940	Senior White and Narayana 1940	279	0/0	0/0	0	0 0	
Jharia Bihar Apr 1938 Sept 1940	Rao 1941	1	0/0	0/0	0	0 0	
Bengal 1939	Iyengar 1940	179	0/0	0/0	0	3 0	
Deltaic Bengal 1939 41	*Idem* 1944	71	0/0	0/0	0	0 0	
Assam 1940 41	Vishwanathan *et al* 1941	12	0/0	0 0	0	0 0	
Waltair Sept 1940 Dec 1941	Senior White and Rao 1943	11	0 0	0/0	0	0 0	
Nizamabad 1940 42	Abraham and Samuels 1944	135	0 0	0/0	0	0 0	

1	2	3	4	5	5	7	8
Udaipur, Raj Aug - Nov *1941*	Roy and Biswas 1942	854	0/6	*0/0 7	6*	0 7*	*Calculated figures
North Kanara May 1942-43	Singh and Jacob 1944	980	0/0	0/0	0	0 0	
Kurnool, Anantapur Cuddapah, 1942-44	Rao *et al* 1946	132	0/0	0/0	9	0 0	
East Central India 1943-45	Senior White 1946	224	0/0	0/0	0	0 0	
Damodar-Hoogly Basin	Jafar and Iyengar 1947	322	0/0	0/0	0	0 0	
Nellore Feb-Aug and Dec 1948	Raghavan and Krishnan 1949	8	0/0	0/0	0	0 0	
Udaipur M P July-Dec. *1949*	Subramanian and Gupta 1950	7121	0/0	0/0	0	0 0	
			0/0	0/0	0	0 0	

25 *Anopheles Philippinensis* Ludlow, 1932

Vector species

26 *Anopheles Pinjaurensis* Barraud, 1932

No dissection record available

27 *Anopheles Pulcherrimus* Theobald, 1902

1	2	3	4	5	5	7	8
Ferozepur 1903	Adie 1905	2/8	0/0	0/0	0	0 0	
Kosi U P	Graham 1810 (a)	12	0/0	0/0	0	0 0	
	DeSousa 1914	95	0/0	0/0	0	0 0*	*(Covell, 1937)

1	2	3	4	5	6	7	8
Amritsar, Punjab	Gill 1917	5	0/0	0/0	0	0 0	
	28 *Anopheles Ramsayi* Covell, 1927						
Cachar, Assam Apr-Dec 1927	Strickland 1929	256	0/1	0/0 4*	1*	0 4*	*Calculated figures
Assam Apr 1927 Mar 1930	Ramsay 1930	287	0/1	0/03*	1*	0 4*	*Calculated figures
Krishnagar Bengal	Sur and Sur 1929	123	0/0	0/0	0	0 0	
Birnagar	Sur and Sur 1929	99	0/0	0/0	0	0 0	
Assam 1927-1935	Ramsay and Macdonald 1936	2217*	4/0	0 /20	4	0 2	*Includes 287 by Ramsay 1930
W Bengal 1933-1940	Sen 1948	140	0/0	0/0	0	0 0	
Orissa coastal plain 1935-1941	Senior White *et al* 1943	556	1/0	0 18/0*	1*	0 018	*Calcultated figures
Hazaribagh 1936-1943	Senior White 1943	27	0/0	0/0	0	0 0	
Chilka lake Apr 1937 Mar 1938	Senior White and Adhikari 1939	16	0/0	0/0	0	0 0	
Bally Calcutta Aug 1937-July 1938	Roy 1939	40	0/0	0/0	0	0 0	
Bengal Nov. 1937-38	Iyengar 1939	524	0/0	0/0	0	0 0	
Bengal 1939	Iyengar 1940	952	0/0	0/0	0	0 0	
Deltaic Bengal	Iyengar 1944	742	1/0	0 1/0*	1*	0 1*	*Calculated figures
Puri Apr 1940 March 1941	Panigrahi 1942	1658	1/0	0 06/0*	1*	0 06*	*Calculated figures

1	2	3	4	5	6	7	8
Waltair Sept 1940 Dec 1941	Senior White and Rao 1943	1	0/0	0/0	0	0 0	
E C India 1944	Senior White 1946	1	0/0	0/0	0	0 0	
Damodars Hoogly Basin	Jafer and Iyengar 1947	31	0/0	0/0	0	0 0	
29 *Anopheles Sintoni* Puri 1929							
No dissection record available							
30 *Anopheles Splendidus* Koidzumi 1920							
Jeypore Hills March Nov 1912	Perry 1914	12/19	0/0	0/0	0	0 0	
Saharanpur Feb Sept 1927	Mayne 1928	258	0/0	0/0	0	0 0	
Mysore S India	Sweet 1929 39	22	0/0	0 0	0	0 0	
Banbassa U P	Clyde 1931	35	0/0	0/0	0	0 0	
Karnal	Macdonald and Majid 1931	26	1/0	*4 0 0	*0	*4 0	*Calculated figures
Singhbhum Hills Sept 1935 Dec 1937	Senior White and Dass 1938	16	0/0	0/0	0	0 0	
Jeypre Hills	Senior White 1937	38	0/0	0/0	0	0 0	
Jeypore Hills Oct 1936 37	Senior White 1938	2	0/0	0/0	0	0 c	

1	2	3	4	5	6	7	8
Eastern Satpura ranges 1946 40	Senior White and Adhikari 1940	56	o/o	o/o	o	o o	
Wynnad 1938-39	Covell and Harbhagwan 1939	55	o/o	o/o	o	o o	
Singhbhum Hills May 1938-April 1940	Senior White and Narayan 1940	11	o/o	o/o	o	o o	
Bangal 1939	Iyengar 1940						
Assam 1940-41	Vishwanathan *et al* 1941	7	o/o	o/o	o	o o	
Nilgiris Feb 1940 41	Russel and Jacob 1942	8	o/o	o/o	o	o o	
Waltair	Senior White and	12	o/o	o/o	o	o o	
Sept 40-Dec 41	Rao 1933	1	o/o	o/o	o	o o	
Jharia Bihar 1941	Rao 1941						
Darjeeling 1941	Khan 1942	6	o/o	o/o	o	o o	
E C India 1944-45	Senior White 1946	48	o o	o/o	o	o o	
North Kanara 1944	Singh and Jacob 1944	1	o o	o o	o	o o	
Khandwa M. P	Subramaniam and	5	o/o	o/o	o	o o	
July 1948 Dec 1948	Dixit 1948	9	o/9	o/o	o	o o	
Udaipur M P July-Dec 1949	Subramanian and Gupta 1950	234	o o	o/o	o	o o	
Vector Species	31 *Anopheles Stephensi* Liston 1901						
	32 *Anopheles Subpictus* Grassi 1899						
Mian Mir	James 1902	496	o o	o o	o	o o	

1	2	3	4	5	6	7	8
Ennur	Stephens and christopher 1902 (*b*)	364	0/0	0/0	0	0 0	
Ferozepur 1903	Adie 1905	1/2	0 0	0/0	0	0 0	
Kairana	Graham 1910 (*b*)	27	0/0	0/0	0	0 0	
Bombay	Bentley* 1911	772	0/0	0/0	0	0 0	*Reported by covell, 1927
Kanara	Mhasker 1915	431	0/0	0/0	0	0 0	
Punjab	Gill 1917	142	0/0	0/0	0	0 0	
Delhi	Hodgson 1914	84	0/0	0/0	0	0 0	
Bimilipatam Madras	Iyear 1927	316	0/0	0/0	0	0 0	
Saharanpur Feb -Sept 1927	Mayne 1928	1650	0/0	0/0	0	0 0	
Udayagiri Madras	Iyear 1929	53	0/0	0/0	0	0 0	
Mopad Madras	King H H and Krishnan 1929 (*a*)	122	0/0	0/0	0	0 0	
Udayagiri Madras	*Idem* 1929 (*b*)	60	0/0	0/0	0	0 0	
Krishnagar Bengal	Sur and Sur 1929	1302	0/0	0/0	0	0 0	
Mysore S India	Sweet 1929 30	3935	0/0	0/0	0	0 0	
Lucknow April Sept 1929	Banerjea 1930	89	0/0	0/0	0	0 0	
Bengal 1933 40	Sen 1948	1564	0/0	0/0	0	0 0	
Tanjore Madras Nov 1936 Jan 1940	Russell and 1940 Rao	13277 (12360/13017)	2/1	*0 01/0	*007/3	*0 02	*Calculated figures

1	2	3	4	5	6	7	8
	Barber and Rice 1928	135/623	0/0	0/0	0	0 0	
Poona							
March July 1937		65	0/0	0/0	0	0 0	
Bengal Nov 1937-38	Iyengar 1939	332	0/0	0/0	0	0 0	
Bally Calcutta	Roy 1929						
Aug 1937 July 1938		4897	2/1	*0 05/0	*2	*0 04	*Calculated figures
Ennore-Nellore	Russell and 1939	4013/					
May 1937-June 1938	Jacob	4893					
		88	0/0	0/0	0	0 0	
Pandharpur Bombay	Soman 1945						
Sept 1937 May 1938		8381	4/1	*0 05/	5	*0 06	*Calculated figures
Ennore Neller	Russell et al 1939	7409/		0 01			
Pattukkotta		8308					
		1	0 0	0 0	0	0 0	
Darjeeling	Gilroy 1939						
June-Nov 1938		509	0/0	0/0	0	0 0	
Wynaad	Covell and 1939						
	Harbhagwan						
1938-39		1625	0/0	0 0	0	0 0	
Jharia Bihar	Rao 1941						
Apr 1938 Sept 1940		576	0 0	0/0	0	0 0	
Deltaic Bengal	Iyengar 1944						
1939-41		387	0 0	0/0	0	0 0	
Nilgiris	Russell and 1942						
Feb 1940-Jan 1941	Biswas						
Assam 1940 41	Viswanathan et al	353	0/0	0/c	0	0 0	

1	2	3	4	5	6	7	8
Nizamabad 1940 42	Abraham and Samuels 1944	2323	o/o	o/o	o	o o	
Darjeeling 1941	Khan 1942	24	o/o	o/o	o	o o	
Udaipur M P Aug 1918 Nov 1941	Roy and 1942 Biswas	115	o/o	o/o	o	o o	
North Kanara May 1942 May 1943	Singh and Jacob 1944	806	o/o	o/o	o	o o	
Kurnool Anantapur & Chaddapah 1942-44	Rao *et al* 1946	4647	o/o	o/o	o	o o	
Damodar Hooghly basin	Jayer and 1947 Iyenger	25	o/o	o/o	o	o o	
Khandwa C P. 1948	Subramanian and 1948 Dixit	30	o/o	o/o	o	o o	
Sri Hasipoth-Nellore Feb, Aug, Dec 1948	Bhagwan and Krishnan 1949	1234	o/o	o/o	o	o o	
Udaipur State M P July Dec 1949	Subramanian and Gupta 1950	502	o/o	o/o	o	o o	
Vector species	33. *Anopheles, Sundaicus,* Rodenwaldt						
	34 *Anopheles, Tessellatus,* Theobald 1901						
North Kanara	Mhaskar 1915	36	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Cachar Assam April Dec, 1927	Strickland 1929	6	o/o	o/o	o	o o	
Mysore	Sweet 1929 30	80	o/o	o/o	o	o o	
Cachar, Assam April 1927 March 1930	Ramsay 1930	95	o/o	o/o	o	o o	
Orissa coastal plain 1935-1941	Senior White 1943	9	o/o	o/o	o	o o	
Jeypore Hills Oct 1936-Sept, 1937	Senior White 1938	1	o/o	o/o	o	o o	
Satpura 1936-1940	Senior White and Adhikari 1940	9	o o	o/o	o	o.o	
Tanjore Nov, 1936 Jan, 1940	Russell and Rao 1940	28	o/o	o/o	o	o o	
Hazaribagh 1936 43	Senior White 1943	18	o/o	o/o	o	o o	
Ennore Nellore May 1937 June 1938	Russell and Jacob 1939	33 (23/33)	o/o	o/o	o	o o	
S Travancore Aug 1937-Aug, 1938	Mathew 1939	79	o/o	o/o	o	o o	
Bengal Nov, 1937-Nov, 1938	Iyenger 1939	4	o/o	o o	o	o o	
Wynaad 1938-1939	Covell and Harbhagwan 1939	113	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Singhbhum Hills May 1938-April 1940	Senior White 1930 Narayana	2	0/0	0/0	0	0 0	
Chilka lake 1939	Senior White 1939 Adhikari	15	0/0	0/0	0	0 0	
Bengal 1937	Iyenger 1940	40	0/0	0/0	0	0 0	
Deltaic Bengal 1939-41	Iyengar 1940	11	0/0	0/0	0	0 0	
Nilgiris Feb, 1940-Jan, 1941	Russell and Jacob 1942	12	0/0	0/0	0	0 0	
Waltair Sept, 1940-Dec, 1941	Senior White and Rao 1940	126	0/0	0/0	0	0 0	
North Kanara May 1942-May 1943	Singh and Jacob 1944	239	0/0	0/0	0	0 0	
Kurnool Anantpur Cuddapat 1942-44	Rao 1946	33	0/0	0/0	0	0 0	
Maldive Island 1944	Covell 1944	160	4/2	*2.5/1.2	*6	*3.7	*Calculated figures
Madras Orissa coast May 1944-Dec, 1945	Senior White 1947 *et al*	9	0/0	0/0	9	0 0	
Maldive Island March 1951	Iyengar *et al* 1953	22	0/1	*0/4 5	*1	*4 5	*Calculated figures
35. *Anopheles, Theobaldi*, Giles, 1901							
Jeypore Hills Mar,-Nov, 1912	Perry 1914	1/1	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
Cashar, Assam April 1927-30	Ramsay 1940	4	0/0	0/0	0	0 0	
Singhbhum Hills Sept, 1935-Jan, 1937	Senior White and Das 1938	5	0/0	0/0	0	0 0	
Jeypore Hills	Senior White 1937	19	0/0	0/0	0	0 0	
Satpura 1936 1940	Senior White and Adhikari 1940	46	0/0	0/0	0	0 0	
Jeypore Hills Oct, 1936 Sept, 1937	Senior White 1938	1	0/0	0/0	0	0 0	
Hazaribagh 1936-43	Idem 1943	39	0/0	0/0	0	0 0	
Poona March July 1937	Barbar and Rice 1938	0/1	0/0	0/0	0	0 0	
Singhbhum Hills May 1938-April 1940	Senior White and Narayana 1940	3	0 0	0 0	0	0 0	
Waltair Sept, 1940-Dec, 1941	Senior White and Rao 1943	1	0 0	0/0	0	0 0	
North Kanara May 1942 May 1943	Singh and Jacob 1944	1	0 0	0 0	0	0 0	
Khandwa C P July, 1948 Jan, 1949	Subramanian and Dixit 1943	102	0/0	0/0	0	0 0	
Udaipur M P. July Dec, 1949	Subramanian and Gupta 1950	1	0/0	0/0	0	0 0	

1	2	3	4	5	6	7	8
		36. *Anopheles, Turkhudi*, Liston, 1901					
Poona March-July 1937	Barbar and Rice 1938	2/10	0/0	0/0	0	0 0	
Pandharpur Bombay Sept, 1937-May 1938	Soman 1945	16	0/0	0/0	0	0 0	
Kurnool, Anantpur and Cuddapali	Rao *et al* 1946	10	0/0	0/0	0	0 0	
Nasik Oct, 1947-March 1948	Bhatt 1949	417	0/1	*0/0 2	*1	*0 2	*Calculated figures
Khandwa M P. 1948	Subramanian and Dixit 1948	5	0/0	0/0	0	0 0	
		37. *Anopheles, Umbrosus*, Theobald, 1903					
Jharia Bihar April 1938-Sept, 1940	Rao 1941	1	0/0	0/0	0	0 0	
Assam 1940-41	Viswanathan *et al* 1941	2	0/0	0/0	0	0 0	
		38 *Anopheles Vagus* Donitz, 1902					
Assam	Chalam 1923	412	0/0	0/0	0	0 0	
Cachar · Assam April-Dec 1927	. Strickland 1929	1341	1/0	0 07/0	1	0 07	*Calculate figures

1	2	3	4	5	6	7	8
Krishnagar Bengal	Sur and Sur 1929	4479	0/0	0/0	0	0 0	
Brinagar Bengal	*Idem*	163	0/0	0/0	0	0 0	
Vizagapatam Madras	Venkataraman 1929	50	0/0	0 0	0	0 0	
Mysore	Sweet 1929-30	903	0/0	0/0	0	0 0	
Cachar Assam April 1927-March 1930	Ramsay 1930	7601	0/0	0/0	0	0 0	
Jorhat Assam	Ramsay 1931	249	0/0	0/0	0	0 0	*Calculated figures
		10452	0/2	0/0 01	*2	*0 01	
Assam	Strickland *et al* 1933	137	0/0	0/0	0	0 0	*Calculated figures
		6874	0/0	0/0 08	1	0 01	
W. Bengal (1933 40)	Sen 1948	(6247/ 6781)					
Tanjore Nov 1936-Jan 1940	Russel and Rao 1940	12'33	0/0	0/0	0	0 0	
Poona March to July 1937	Barbar and Rice 1938	697	0/0	0/0	0	0 0	
Bengal Nov 1937-38 Nov	Iyengar 1939	63	0/0	0/0	0	0 0	*Calculated figures
Bally Calcutta Aug 1937 July 1938	Roy 1939	3151	0/1	0/0 c8	1	*00 3	
Ennore, Nellore Pattukkotai Jan 1937 March July 1937	Russell *et al* 1939	(3103/ 3149)					

1	2	3	4	5	6	7	8
Ennore Nellore May	Russle *et al* 1939	26 (24/26)	o/o	o o	o	o o	
Pandharpur Bombay Sept 1937 May 1938	Soman 1945	1	o/o	3/o	o	o o	
Darjeeling June Nov 1938	Gilroy 1939	16	o/o	o/o	o	o o	
Wynaad 1938 1939	Covell and Harbhagwan 1939	561	o o	o/o	o	o o	
Jharia Bihar April 1938 Sept 1940	Rao 1941	1843	o/o	o/o	o	o o	
Deltaic Bengal 1939 41	Iyengar 1944	2607	o/o	o/o	o	o o	
Assam 1940 41	Vishwanathan 1941	3396	o/o	o/o	o	o o	
Nilgiris Feb 1940-Jan 1941	Russel and Jacob 1942	464	o/o	c/o	o	o o	
Nizamabad 1940 1942	Abraham and Samuels 1944	11	o/o	o/o	o	o o	
Darjeeling 1941	Khan 1942	475	o/o	o/o	o	o o	
Uda pur C P Aug Nov 1941	Roy and Biswas 1942	41	o/o	o/o	o	o o	
North Kanara 1944	S ngh and Jacob 1944	796	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Kurnool, Anantpur Cuddapah.	Rao *et al* 1946	65	0/0	0/0	0	0 0	
Damodar-Hoogly basin	*Jafer et al.* 1947	110	0/0	0/0	0	0 0	
Nellore Feb-Aug-Dec 1948	Raghawan and Krishnan 1949	407	0/0	0/0	0	0 0	
Udaipur M P. July-Dec 1949	Subramanian and Gupta 1950	54	0/0	0/0	0	0 0	

39. Anopheles *Varuna* Iyenger, 1924

Vector Species

1	2	3	4	5	6	7	8
Ennore Nellore May	Russle *et al* 1939	26 (24/26)	o/o	o/o	o	o o	
Pandharpur Bombay Sept 1937-May 1938	Soman 1945	1	o/o	3/o	o	o o	
Darjeeling June-Nov 1938	Gilroy 1939	16	o/o	o/o	o	o o	
Wynaad 1938-1939	Covell and Harbhagwan 1939	561	o o	o/o	o	o o	
Jharia Bihar April 1938 Sept 1940	Rao 1941	1843	o/o	o/o	o	o o	
Deltaic Bengal 1939 41	Iyengar 1944	2607	o/o	o/o	o	o o	
Assam 1940-41	Vishwanathan 1941	3396	o/o	o/o	o	o o	
Nilgiris Feb 1940-Jan 1941	Russel and Jacob 1942	464	o/o	c/o	o	o o	
Nizamabad 1940 1942	Abraham and Samuels 1944	11	o/o	o/o	o	o o	
Darjeeling 1941	Khan 1942	475	o,o	o/o	o	o o	
Udaipur C P Aug -Nov 1941	Roy and Biswas 1942	41	o/o	o/o	o	o o	
North Kanara 1944	Singh and Jacob 1944	796	o/o	o/o	o	o o	

1	2	3	4	5	6	7	8
Kurnool, Anantpur Cuddapah.	Rao *et al* 1946	65	o/o	o/o	o	o o	
Damodar-Hoogly basin	Jafer *et al.* 1947	110	o/o	o/o	o	o o	
Nellore Feb-Aug-Dec 1948	Raghawan and Krishnan 1949	407	o/o	o/o	o	o o	
Udaipur M P. July-Dec 1949	Subramanian and Gupta 1950	54	o/o	o/o	o	o o	

39 *Anopheles Varuna* Iyenger, 1924

Vector Species

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